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ABSTRACT

Research on the utilization of educational media, or electronic classroom instructional aids, in primary schools in developing countries is reviewed in this paper. Five kinds of hardware--radio, television, computers, videodiscs, and hand-held electronic devices--are compared according to cost and learning effectiveness. A model of learning production is used to define the educational system in terms of its interaction with family and society, and to illustrate the relationships among the components of educational management, which include content, instructional materials, classroom management, physical facilities, and learning technology. Radio was found to be the most cost effective means of improving both scope and quality of instruction. Effectiveness is enhanced if the technologies are used in combination with curriculum development, instructional resources, administrator support, and teacher training. A comparative table, describing seven educational interventions, a diagram of learning production, and an extensive bibliography are included. (LMI)

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Education Development Discussion Papers

USING INSTRUCTIONAL HARDWARE FOR PRIMARY EDUCATION IN DEVELOPING COUNTRIES:

A Review of the Literature

by
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MARCH 1982

B • R • I • D • G • E • S
Basic Research and Implementation in DevelopinG Education Systems

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ABSTRACT

This paper reviews research on "educational media," that is, the electronic hardware that constitutes an alternative to teachers or printed lessons. Five kinds of hardware are included: radio, television, computers, videodiscs, and hand-held electronic devices.

Anzalone compares the various hardware in terms of cost and effect on learning. However, adequate evaluation research has been done only with respect to radio and instructional television, and in these cases detailed information is presented.

Using the BRIDGES model of learning production, Anzalone's diagram defines an education system by its interaction with family and society. Family and society determine much of what takes place in schools, but they are in turn effected by the outcome of that schooling. The diagram also shows that educational management and planning (as done by teachers, principals, supervisors, etc.) is comprised of interrelated factors that include: content, instructional materials, classroom management, physical facilities, and learning technology. Anzalone shows how the choice of learning technology influences these other factors.

Several clear-cut conclusions can be drawn from this review. The first is that television is not a cost-effective alternative, in either rich or poor countries, in comparison with conventional technologies based on classroom teachers. Countries that began with instructional television in primary schools found them too difficult and costly to manage, and have abandoned them. On the other hand, radio is an effective means of improving both the coverage and the quality of instruction in primary schools. Anzalone notes that radio should not be seen primarily as a means to replace teachers. On the contrary, the combination of radio instruction--at per student costs close to that of a textbook--with teacher training leads to significant gains in learning.

Also, none of the other kinds of instructional hardware have yet been shown to be cost-effective in the production of learning in primary schools. There is little evidence to justify the enthusiasm for widespread introduction of microcomputers in classrooms. Research in the United States suggests that while computers help in some cases, particularly in practice and drill on repetitive subjects, there is no evidence that they are a cost-effective substitute for teachers.

Videodiscs are described as a sophisticated technology with great potential that is beyond the reach of schools even in the rich countries.

The review reports one systematic study on hand-held electronic devices, which are small microprocessor driven devices

that teach basic spelling and arithmetic to young learners. These devices, which are relatively inexpensive if they can be used over a period of time, were shown to be effective in one country. No follow-up research has been done.

The last and most important conclusion to be drawn from this review is that learning technologies based on hardware are by themselves sterile. Unless they go hand in hand with improvements in content, with increased use of instructional resources, and with greater administrative support, they have little chance of contributing to either the quality or the quantity of primary education.

A companion to this paper, Using Soft Technologies of Learning for Primary Education in Developing Countries, by Sivsailam Thiagarajan and Aida L. Pasigna, reviews research on those instructional technologies (such as new forms of classroom organization) that do not require investments in hardware. That paper and this one should be read together, as the "hard-soft" distinction between instructional technologies is arbitrary: together the papers provide a comprehensive coverage of what is known about the effectiveness and costs of many kinds of instructional technologies.

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I. INTRODUCTION

The use of learning technologies may provide developing nations with the means for extending access and improving the quality of education at substantially lower costs than traditional means. By learning technologies we mean procedures and techniques based upon theories which help to design, organize, deliver, and manage educational information and the learning process. These procedures and techniques may or may not be mediated through devices and instruments.

In a companion review, "Literature Review on the Soft Technologies of Learning," we examine the procedures and techniques--what might be called the "soft" aspect--of learning technology. But for the present review, we want to focus on the devices aspect of learning technology, or the electronic media used to automate, enhance, or extend parts of the learning process. We refer to this "hard" aspect of learning technology as instructional hardware.

Since the purpose of this review is to determine how and to what extent instructional hardware is or might be significantly involved in primary education, we do not address distance education projects at the post-primary level or primary school equivalency programs for older students--areas where instructional hardware has been used with considerable success.

We define instructional hardware as electronic presenters of instructional sequences that are significant enough in scope and curricular importance to constitute an alternative to lessons usually provided by teachers or textbooks and similar printed materials. In some cases, the wider concept of educational media can and will be used interchangeably with instructional hardware.

We look specifically at the use of radio, television, computers, videodiscs, and hand-held electronic devices to support primary school education in developing countries.

Our reasons for focusing on these five possibilities are discussed below.

We recognize that--since, for example, we learn from television programs and not from television--looking at instructional hardware per se is problematic. The literature is often vague about the content or method that is being delivered, either because it is believed that these are less important than the attributes of the medium itself or because of an understandable and often premature desire to generalize about the potential educational value of the medium--especially for guiding policy or investment decisions. We elaborate later in the review on the confounding influence of method on the medium.

We begin the review by discussing how we conducted our literature search and our selection of instructional hardware to be examined. We then orient our review within the framework of the BRIDGES learning model. Our discussion highlights some major issues involved in comparing and generalizing from research on instructional hardware in developing countries. Finally, we review evidence and draw conclusions about each type of instructional hardware with respect to whether their introduction would permit an education system to reduce costs while maintaining coverage and quality.

II. HOW THE LITERATURE SEARCH WAS CONDUCTED

Our review is based upon a search of a disparate body of literature, mostly written in the U.S., that includes books, articles, unpublished research reports, project evaluations, and bibliographies. We conducted on-line searches of the DIALOG databases (including ERIC, Dissertation Abstracts International, PsycINFO, and SOCIAL SCISEARCH) and obtained abstracts of relevant literature. Microfiche versions of several key documents were obtained. In general, we did not find these databases to be a good source of information on instructional hardware in developing countries.

Advice and documents were received from specialists including John Mayo, Jamesine Friend, Jean Meadowcroft, Klaus Galda, Michael Laflin, Clifton Chadwick, Judy Brace, Peter King, Maurice Imhoof, Tom Eisemon, and Noel McGinn. Jim Hoxeng and Julianne Gilmore of the Office of Education, Bureau for Science and Technology of the U.S. Agency for International Development, helped us obtain several important documents. We also obtained leads (and confirmation of a lack of Third World literature on educational applications of computers) from participants in the UNESCO/Stanford symposium on "Computers in Education: The Role for International Research" held in Palo Alto in March, 1986.

The literature we found is identified in the bibliography. Cooper (1984) warns of two threats to validity associated with gathering data for literature reviews: (a) not locating all studies pertinent to the topic of interest, and (b) elements or individuals in the retrieved studies not representing all individuals or elements in the target population. We tried to minimize the first threat by circulation of this draft to other investigators in the field to determine what may have been missing. The second threat is not so easily dealt with. Not all characteristics of primary school pupils in developing countries are represented by the studies reviewed, and it is difficult to see how they could be.

III. SELECTION OF INSTRUCTIONAL HARDWARE

All of the instructional hardware considered in this review, are examples of what Schramm (1973) called "big media." In making this definition, Schramm considers complexity of design and production, the size of the audience, possible educational significance, and the complexity of support necessary for success in school settings. "Big media" originated in systems for communications, entertainment, advertising, computation, and data storage and retrieval--not as educational tools.

This review looks at various kinds of instructional hardware capable of providing a significant sequence of instruction and used as an alternative or supplement to lessons provided by teachers or textbooks and similar printed materials. This excludes various audiovisual devices or objects a teacher might use in a lesson to aid comprehension, stimulate imagination, or otherwise occupy a student's time. We include educational films and filmstrips in this category, since their role in primary school instruction has usually been to enrich or supplement regular lessons.

We consider kinds of instructional hardware that are or might one day be feasible for primary schools in developing countries. This is a subjective determination. It is conditioned by the way the instructional hardware is used, and does not suggest that all instructional hardware will be feasible in all schools in all countries. The following kinds of instructional hardware are examined:

- Radio. Radio is the instructional hardware most widely used in primary schools in developing countries. Radio includes both commercial and public broadcast channels. Audiocassettes provide instruction similar to lessons broadcast by radio. So far, they do not appear to have been widely used for primary education in developing countries. The same holds true for audiovisual combinations like audiovision or radiovision.

- Television. Television has been much less widely used than radio for primary education in developing countries. There are, however, several important national experiments with educational television. We limit ourselves

to instructional television related to the school curriculum and not children's "open broadcast" programs with incidental or deliberate educational content. Videocassettes are now becoming common throughout the Third World. They free educational television from rigid broadcast schedules and thereby make television a more convenient (although more expensive) medium for classroom use.

- Computers. The use of computers in primary education in developing countries is not yet widespread. Growing interest in computers, recognition of their impact on society, falling prices of hardware, and the "demonstration effect" of their increasing use in developed countries are likely to cause this to change, especially in well-equipped urban schools.

- Videodiscs. Videodiscs are just now on the horizon for use in education in countries like the U.S. Their use in some primary schools in developing countries is admittedly speculative but not inconceivable at this time. Developments with mass storage CD ROM (compact disc read-only memory) technology could make this a possibility in some places and could well be offered in the school library of the future.

- Hand-held Electronic Devices. Hand-held electronic learning devices include microprocessor-driven drill and practice aids like the Speak & Spell and pocket calculators. Despite their relatively low cost and ease of operation, their use in instruction in developing countries has so far received little attention.

There are other kinds of instructional hardware that have been used effectively, often in combination with other media, in classrooms and distance teaching programs both in developed and developing countries. Bates (1982) provides a good discussion of the range of delivery media and comparative advantages of different systems. Some instructional hardware that might prove useful for education in developed countries has had little or no application at the primary school level in developing countries. We do not consider several varieties of instructional hardware that have been or might soon be used in developed countries or

for distance education at post-primary levels in developing countries, including teleconferencing, telephones, two-way radio, videotext, teletext, interactive cable, computer-augmented television, electronic blackboards, still-picture television, and slow-scan television. Similarly, the use of satellites is not considered, since we consider satellites as carriers rather than as presenters of instruction.

IV. A MODEL OF LEARNING

The purpose of this review is to determine how and to what extent learning technology is or might be useful in primary education in developing countries. We ask whether the learning technology cum instructional hardware variables really need to be included in a model of learning separately from, say, the instructional content and materials variables, and whether the alternative or supplementary instruction provided by these systems adds to the explanative or predictive power of the model.

The BRIDGES theoretical model of learning production (see diagram on the next page) situates the educational system in a position where it can prevent "social origin" from determining "social destiny." At the perimeter of the educational system is the set of management and planning functions that steers the system. Within the perimeter are schools. Within schools are blocks of variables (including learning technology) that may be involved in the production of learning. These variables interact with each other and with inputs--skills, aspirations, and knowledge brought to school from the family and community and policies and resources supplied by society. The production of learning results in values, skills, and knowledge returning to the family and society. These outcomes are produced with varying degrees of effectiveness and efficiency.

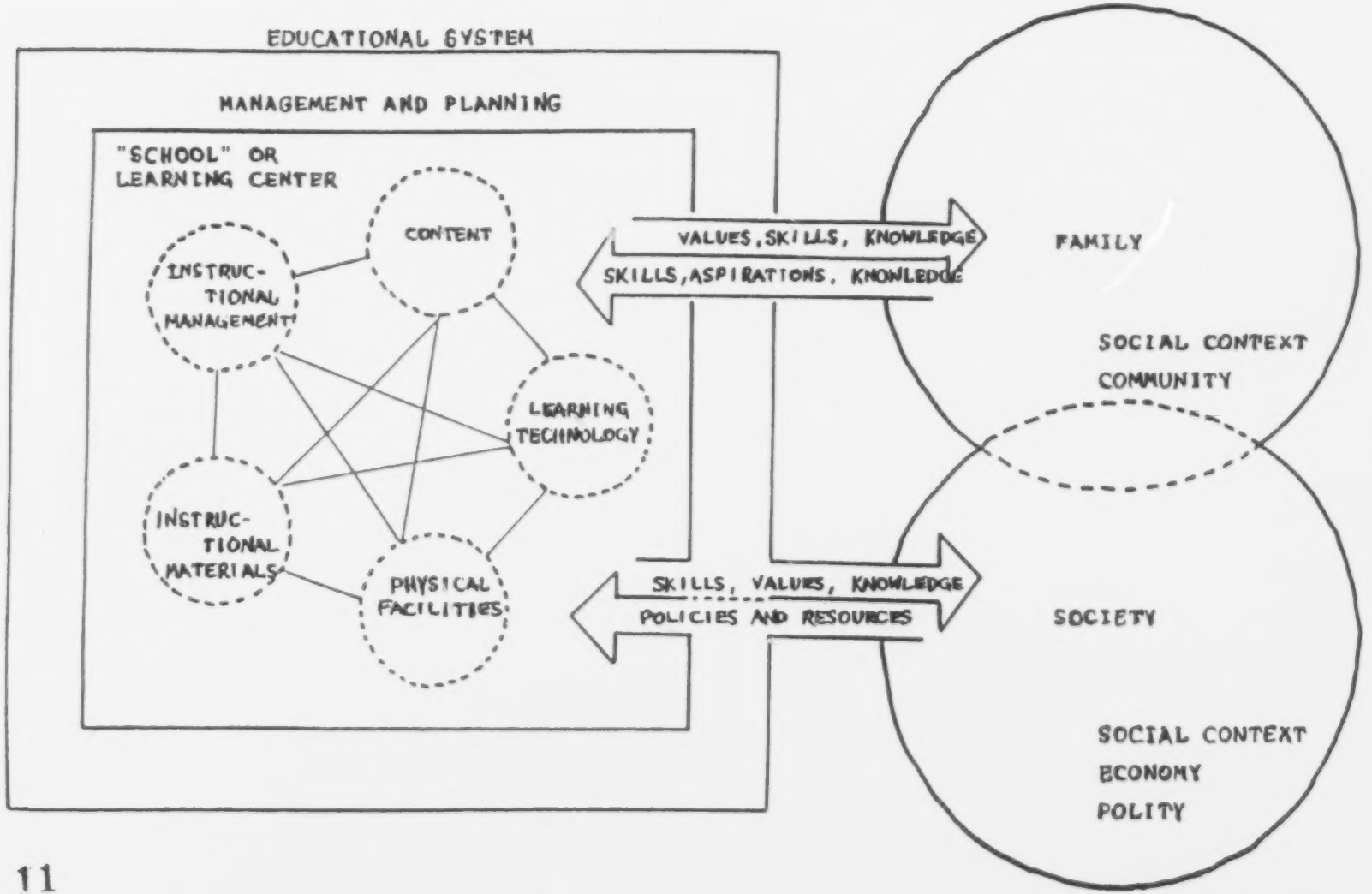
1. "Within School" Relationships

Both intuition and the literature suggest that the most important relationship between the use of instructional hardware and other "within school" variables is the relationship with instructional management. Indeed, the literature is rich with examples of the insufficient attention paid to this relationship and the disastrous consequences of this neglect.

The two most important aspects of the relationship between use of instructional hardware and instructional management are teacher acceptance of the technology and teacher competence in its use.

Teacher acceptance seems to depend to some extent on the type of, and the purpose to which instructional hardware is being

FIGURE 5.1 CONCEPTUAL MODEL OF LEARNING PRODUCTION



applied. The introduction of new technology in the production of learning, as in the production of other social products, often anticipates a substitution of capital for labor in order to achieve a net reduction in cost. The substitution of instructional hardware for labor in educational settings proves to be economical when more highly trained teachers can be replaced by less trained (and lower paid) teachers, or when there is less frequent contact between teacher and student (Jamison and Orivel, 1982). In many instances, the relationship between teachers and the use of alternative instructional hardware may be fundamentally antagonistic. Our review treats the substitution of capital for labor as a policy issue rather than as a classroom management issue.

We believe that the most important question about teacher acceptance is the following:

- Does different instructional hardware meet with and sustain different levels of teacher acceptance?

The second aspect of the relationship between instructional management and the use of instructional hardware has to do with what is necessary to operate the system. This involves both the teacher's existing knowledge and skills as well as whatever additional training or orientation is required to operate instructional hardware. There is considerable variation here. Some teachers have been oriented to a new curriculum delivered by radio in as little as three hours. However, to prepare them for a more complex intervention, say, to teach LOGO, considerably more training is required. The most important questions are:

- What knowledge and skills are required of teachers to use instructional hardware and, perhaps, to learn a new instructional role?

- Do knowledge and skills gained by the teacher from working with instructional hardware transfer to areas where such hardware is not being used?

A second important "within school" relationship is between the use of instructional hardware and content.

The questions which should be addressed are:

- How readily are the various school subjects taught by different kinds of instructional hardware?

- Does this vary with grade level?

- Does use of instructional hardware permit (or

dictate) adding or deleting content in the curriculum or acquiring skills within a subject that are either new or possible at an earlier age?

The third "within school" relationship is between the use of instructional hardware and instructional materials. The important questions we consider are the following:

- How effectively and how cheaply can electronic messages substitute for printed messages?

- What visual supports are necessary for audio media and vice versa?

The final "within school" relationship is between instructional hardware and the physical facilities of the school. Clearly, the condition of school facilities, especially lack of electricity, would rule out the use of some instructional hardware and constrain the use of others. For many people, policy makers, and teachers, poor facilities often render incongruous the introduction of alternative instructional hardware. The face validity of the priority of improving basic facilities over the introduction of instructional hardware is powerful. Investments in improved school facilities are likely to be made for reasons apart from school achievement and apart from accommodating or facilitating the use of alternative instructional hardware. The important research question appears to be how alternative instructional hardware can or cannot be made to operate in the typically abject conditions of remote rural or crowded urban schools.

2. <u>School-Family Relationships</u>

The BRIDGES model (page 6) highlights the reciprocal process by which skills, aspirations, and knowledge are brought to school by the student and values, skills, and knowledge return to the family and community. With respect to the first of these, the major questions are: Do factors beyond a student's control, such as socioeconomic background, ethnicity, gender, mother tongue, or geographic location of his/her home affect entry into school, continuation of schooling, and what is learned while in school? To what extent are these changed or reinforced by the use of alternative instructional hardware in instruction?

Issues related to how values, skills, and knowledge return to the family and community are not generally treated in the literature. It is difficult enough to measure the gross effects of either schooling or the content of particular school subjects on family or community life. It would be extremely difficult to disentangle or even detect the effects of what may be very

limited contact with instruction provided by any kind of instructional hardware.

3. School-Society Relationships

A student needs certain skills, values, and knowledge to participate in adult life. These skills are to a large extent manifest while in school and, after leaving school, affect and are affected by social and economic life.

It is the latter part of this process that is of most interest to policy makers. It is the former part, however, that receives attention in the literature. Apart from the occasional speculation that exposure to media in schools contributes to a weakening of traditional rural values, causing a drift to the cities, there appear to be few attempts to examine the "external efficiency" of instruction provided by instructional hardware. As was argued above, if long-term effects resulting from what is often episodic contact with alternative instructional hardware do occur, they would be extremely difficult to detect. The problem of assessing the external efficiency of learning associated with alternative instructional hardware is particularly germane in the case of the newer devices, where the introduction of computers into education is often preparation for the economic and social possibilities engendered by the rapidly developing global information society. These claims are only beginning to be examined in countries like the United States (Carnoy et al., 1986).

The use of other instructional hardware has largely been predicated on the more modest claims that they affect learning or internal efficiency within schools. The variables most frequently treated in the literature are achievement in different subjects, attendance, repetition of grades, and continuation in school. Often, there are measures of attitude toward a school subject or the instructional hardware itself. The adequacy of these measures and the difficulties in comparing them with the effects of conventional teaching is discussed in the following section. The notion of internal efficiency could be treated as a "within school" consideration. We treat it in this section in order to keep discussion of outcomes in the same place and to emphasize that internal efficiency is something wider than classroom process, and something closely related to policies and resources.

The policies and resources that determine the use of instructional hardware in schools are also of fundamental importance. An understanding of how policies--or perhaps more accurately, actions of policy makers--affect the selection, introduction, and continued use of instructional hardware is essential and largely lacking in the literature. Perhaps the single most important question here is:

- Has the introduction of instructional hardware found a sustained or expanded place in national educational policies?

The fact that particular resources are needed for instructional hardware is of indisputable importance. This fact has received considerable attention, and this literature is considered throughout the review.

At the level of policies and resources, two questions are important:

- Has the introduction of an alternative instructional hardware permitted a substitution of lower skilled (and lower paid) instructional personnel or a reduced role for the teacher in the improvement of instruction or extension of schooling?

- Where introduction of instructional hardware does not permit the substitution of capital for labor, what are the additional educational costs and their implications?

V. ISSUES

There are two issues of special importance that make it difficult to determine whether instructional hardware can contribute significantly to the learning in schools: the medium versus method issue and the equivalence of costs and outcomes issue.

1. The Medium versus Method Issue

Advocates of the use of media in education often point to various attributes of the media as being particularly facilitative of learning. They cite such things as the immediacy and liveliness of radio, the ability of television to command and hold attention and to provide complex visual stimuli, and the capability of computers to offer immediate and individualized feedback. Explanations for poor results from particular instructional media often cite the failure of the instructional designers to make good use of the features of the medium.

There are those who dispute the claim that various features of media affect learning. Clark (1983, p.445) argues that current summaries and meta-analyses of media and learning studies suggest that "media do not influence learning under any

conditions." He contends that in the instances where large changes in student achievement have been associated with the use of media, such as (and this is his example) with educational television in El Salvador, the changes are attributable to curriculum reform and not the medium. Clark insists that better performance associated with use of media is explained by the confounding effects of instructional method, and to a lesser extent, novelty effects.

Others take exception with Clark's hypothesis. Petrovich and Tennyson (1984) argue that the meta-analyses Clark uses involved classroom studies without adequate controls to test his hypothesis, that Clark did not adequately take into account how various components of the human information processing system affect learning, and that recent evidence from computer-assisted instruction studies do not support his view.

The medium versus method issue is clearly relevant to the literature on instructional hardware in developing countries. However, it is often difficult to determine what instructional method is being used in a particular media application and hazardous to generalize about what methods work best with what media. In an application where the method is well-defined, such as the interactive radio method, there is likely to be wide agreement with Clark, that the outcomes are attributable to use of the interactive method specifically rather than to the medium of radio generally. For policy makers in developing countries the medium versus method issue may not be critical. Even if it can be shown that it is an instructional method rather than a medium that is responsible for gains in student achievement, the use of media may often be the only means to deliver the method efficiently.

2. <u>Equivalence of Costs and Outcomes</u>

Critics of the use of instructional hardware in developing countries raise several related questions about how costs and outcomes are analyzed and interpreted. Carnoy and Levin (1975) argue that evaluators' "modes of analysis" have possibly been contaminated because of the advocacy positions taken with respect to the media being evaluated and because of their close associations with the agencies that have sponsored both the implementation and evaluation of projects being examined. Emery (1985) takes a similar view.

Carnoy and Levin (p.387) identify two types of bias in the evaluations of various applications of instructional hardware in education in developing countries: (a) the use of "deficient data" when they favor instructional technology over traditional alternatives, a phenomenon they refer to as "benefit-of-the-doubt" bias, and (b) "narrowing of the scope of analysis to those items on the agenda of the sponsoring agency while ignoring other

effects."

Carnoy and Levin (p.388) submit that cost analyses of applications of instructional technology are faulty because "in almost every case the reported costs of instructional technologies are understated relative to their true costs." According to them, this results from basing cost estimations upon "drawing board" approaches, which, they contend, are invariably lower than actual costs. Moreover, they suggest that cost estimations tend to ignore costs of such things as "contributed facilities" and technical assistance costs associated with development of the instruction to be provided.

The second bias identified by Carnoy and Levin (p.391) is the use of "a narrow measure of educational attainment" which tends to "overstate the attractiveness" of the technology being evaluated. They argue that the outcomes of education go far beyond performance on measures of reading and mathematics. This is, they note:

> an especially serious problem in a cost-effectiveness study because the evaluation instruments are invariably designed to compare the instructional approaches on the basis of what the instructional technology is designed to achieve rather than the far larger outcomes that the traditional systems of instruction focus on. (p. 391)

We believe that these contentions should be taken as important cautions in interpreting the literature on the use of instructional hardware to support primary education in developing countries. However, two points should be made. First, cost analyses that have appeared subsequent to the time period with which Carnoy and Levin were concerned appear to approach estimation of "true costs" by taking into account actual costs and fixed costs for instructional development (see, for example, Jamison, Klees, and Wells, 1978; Jamison and McAnany, 1978; Leslie and Jamison, 1980). Second, although few would disagree that educational outcomes include more than performance on achievement tests in reading and mathematics, the importance assigned to these attainments by educational systems all over the world makes it difficult to accept the idea that emphasis on these outcomes in evaluations is a self-serving "narrowing" of the educational process by the advocates of instructional technology. In recent evaluations of the use of instructional hardware, there does appear to be sensitivity to the issue of whether an equivalent range of educational outcomes is being compared (see, for example, Friend and Kozlow, 1985).

VI. COMPARING EDUCATIONAL OUTCOMES

Our attempt to determine whether and how instructional hardware can be significantly involved in the production of learning in primary schools in developing countries requires that we evaluate and summarize information about educational outcomes. There are enormous difficulties in producing a synthesis of research findings from studies involving the use of different media since applications have been undertaken in different countries, at different points in the educational process, and for different educational purposes.

In the past several years, research reviews have made increasing use of quantitative meta-analytical procedures for evaluating and summarizing research on educational outcomes. One of the most widely used methods of meta-analysis is the statistical measure called effect size. This is a comparison of differences between an experimental and control group. The effect size is simply the difference between the means of the experimental and control group divided by the standard deviation of the control group (Glass, 1977; Glass, McGaw, and Smith, 1981).

Walberg (1984b, p.216) describes the advantages of using effect sizes:

> Effect sizes permit a rough calibration of comparisons across tests, contexts, subjects, and other characteristics of studies. The estimates, however, are affected by the variances in the groups, the reliabilities of the outcomes, the match of curriculum with outcome measures, and a host of other factors, whose influences, in some cases, can be estimated specifically or generally. Although effect sizes are subject to distortions, they are the only explicit means of comparing the sizes of effects in primary research that employs various outcome measures on nonuniform groups. They are likely to be necessary until an advanced theory and science of educational measurement develops ratio measures that are directly comparable across studies and populations.

Effect sizes are expressed in standard deviation units. Although this is often not readily understood by persons without a background in research, effect sizes can be expressed in terms of changes in percentiles. For example, the meta-analysis of 32 research studies on the effects of computer-assisted instruction on achievement of elementary school students in the United States conducted by Kulik, Kulik, and Bangert-Drowns (1985), found an average effect size of .47. This means that the use of computer-assisted instruction had the effect of raising the mean of pupil

achievement from the 50th percentile, which would be average performance without computer-assisted instruction, to the 68th percentile of that group. In interpreting effect sizes, Walberg (1984b, p.222) reports that from samples of recent educational research, an effect size of .20 (equivalent to raising the mean from the 50th to the 58th percentile) is about average and one of .45 is "considered large and exceeds about 84% of those typically found in educational research." Research syntheses undertaken by Walberg (1984a, p.23) show, for example, that IQ has a strong effect on learning with an effect size of .71. Similarly, of various methods used in instruction, reinforcement or reward for correct performance had the largest overall impact, with an effect size of 1.17 (equivalent to raising means from the 50th to the 88th percentile).

We have attempted in this review to use effect sizes to evaluate and compare achievement gains reported in the literature on the use of instructional hardware in primary education in developing countries. In the present draft, we are limited to the interactive radio case studies, where evaluations provide necessary information.[1]

For purposes of formulating educational policy and allocating resources within educational systems in developing countries, the important question to be answered is: How large an effect is required to make use of instructional hardware compelling? Is an effect size of .45 (or, raising the mean from the 50th to about the 68th percentile)--judged to be large in developed countries--large enough to motivate policy makers in a developing country to undertake a major investment and reorganization of school instruction?

VII. SELECTED INSTRUCTIONAL HARDWARE

The possibilities for using instructional hardware to improve or extend education in developing countries have been consistently acknowledged since the 1960s. Perhaps the landmark endeavor of the early era was the four part series New Educational Media in Action (1967), edited by Wilbur Schramm. This collection included three volumes of case studies and a synthesis entitled The New Media: Memo to Educational Planners (Schramm et al., 1967). These books emerged from a project undertaken by UNESCO's International Institute for Educational Planning under a contract from the U.S. Agency for International Development. The series includes twenty three cases studies from

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[1]This was made possible through discussions and sharing of information with Jamesine Friend, Peter Spain, and Julianne Gilmore.

seventeen countries and covers a wide range of educational applications for the use of radio and television. The wide analytical sweep of these documents, their great readability, their generally upbeat appraisal of the educational possibilit for the "new" media have set the tone for international discussions for years to come.

At least twenty years have passed since radio and televisi emerged as possible transformers of education in developing countries. At a time when we are still trying to assess the effects of what has been called the "first electronic revolution," by considering whether instructional hardware, especially radio, will or should play a wider role in primary education, the "second electronic revolution" (computers, videodiscs, and similar devices) is already arriving at the door of schools in these countries.

We look now at the literature on specific instructional hardware: radio, television, computers, videodiscs, and hand-held learning devices. We look retrospectively at developing countries' experience with radio and television and futuristically at the possibilities for computers, videodiscs, and hand-held learning aids. Our treatment of radio is the most detailed at this point.

1. Radio

Radio signals have come to reach increasingly large numbers of citizens in developing countries. Between 1965 and 1982, the number of radio receivers per thousand inhabitants has, for example, grown from 12 to 131 in Indonesia and from 11 to 177 in Sierra Leone (UNESCO, 1984). McAnany (1973) was correct when, more than a decade ago, he described radio as the "most universal mass medium of communication."

With improvements in the processes of manufacturing receivers and developments in the use of transistors and batteries, radio became affordable, portable, and practical--even in remote regions. Radio has, since the 1960s, played a varied and important role in social and economic development efforts. There is extensive literature describing applications of radio, often in combination with other media, to agricultural extension and farmer education, adult literacy and basic education, health, nutrition, population education, and family planning. (See, for example, Clearinghouse on Development Communication, 1978; 1982.)

Radio has also been used in various ways in classrooms in developing countries, including primary school instruction. In the 1960s, Thailand emerged as an example of how the primary school curriculum could be enriched at relatively low cost through radio broadcasts. In 1967, about 800,000 pupils were

receiving radio lessons in several subjects (UNESCO, 1967). The experience in Thailand is summarized on page 23, a.c. We discuss various aspects of Thailand's experience later in this section and in connection with the questions raised related to the BRIDGES model.

In 1972, UNESCO's International Commission on the Development of Education noted this about radio:

> People often seem to be deterred by the reputedly greater efficiency of other media which, however, have the major defect, compared with radio, of being unable to hope for such widespread distribution--or anything like it--for a long time to come. The very low cost and adequate reliability in all climates of miniature transistor radios mean that radio broadcasting should more and more be recognized as a particularly suitable medium for educational purposes (Faure et al., 1972, p.122).

Radio's potential for delivering education in school was not, and perhaps is still not, apparent to all educators. As the Faure Commission noted, the attractiveness of television largely pre-empted consideration of radio as an educational tool in many places. Moreover, radio is not now widely used in classrooms in the early industrialized societies, thus precluding any kind of "emulation effect" to stimulate applications in developing countries.

The early promise of radio related closely to some of its attributes as a communication medium that offered potential advantages for instruction. These included radio's liveliness and immediacy and its apparent ability to require concentration of attention and mental effort on the part of students. Schramm et al. (1967) cited four other potential advantages:

- Radio can spread and equalize learning opportunities while raising educational quality
- The old media such as textbooks could share the substance of teaching; the new media like radio can share the dynamics of teaching
- Radio can provide demonstrations to schools that could not otherwise afford them

Radio's potential was seen by Jamison and McAnany (1978, p.12) to fall into three categories: "improving educational quality and relevance; lowering educational costs (or the rate of increase of costs); and improving access to education, particularly in rural areas."

These were formulations of educational potential and not an assessment of effects observed through research. The early empirical "basis" for the effectiveness of radio is outlined in Jamison and McAnany (1978). They cite the survey by Chu and Schramm (1967), which concludes that under proper conditions students can learn from any of the media that were currently available and that not only is a visual channel not always necessary for learning, sometimes it can interfere with it. These conclusions were shared by Forsythe (1970). Jamison, Suppes, and Wells (1974, p.33-34) reached similar conclusions but admit that the empirical basis for these conclusions was small:

> Radio has been used extensively for formal classroom instruction in the United States (more in the past than in the present) and elsewhere. There exist, however, only a limited number of good evaluations of the effectiveness of instructional radio. These evaluations indicate that instructional radio can be used to teach most subjects as effectively as a live classroom teacher or ITV.

The radio initiatives and the case studies reported during the 1970s were helpful in moving from an assessment of potential to an assessment of effects, even if the information collected on learning outcomes was often sparse or potentially unreliable. Two rich case studies came from Mexico: the Tarahumara Radio Schools (Schmelkes de Sotelo, 1972; 1977) and Mexican Radioprimaria (Spain, 1977). Insightful commentaries on these case studies followed in Jamison and McAnany (1978). To facilitate our present analysis, these case studies have been broken down into summary form on the following pages.

Both of the Mexican radio initiatives were attempts to develop low cost extensions of primary education in underserved areas. Both used radio for direct rather than supplemental teaching and for several subjects. Both report achievement data that, if not clearly indicative of radio's effectiveness, at least point in that direction. Each project failed in one of its principal objectives: the Tarahumara schools failed to promote much equity among a disadvantaged sub-population and Radioprimaria essentially failed in its objective to use radio as a substitute for hiring more teachers in a school. Both projects demonstrated that receiving radio signals and keeping radio sets functioning properly were matters not to be taken lightly by educational planners. Despite the promise shown by these two efforts, both were abandoned and seem to have fallen victim to the prevailing disenchantment with formal education witnessed during the 1970s.

Two similar initiatives undertaken during the 1970s are

Intervention	Medium	Coverage
Radio Project in Thailand	Radio	1957/8: 286 schools (220 elementary and 66 secondary 1959: 500 schools 1962: 1,000 schools 1965: 5,000 schools, 800,000 students
Country/Region	**Years Being Reviewed**	**Studies Providing Data**
Thailand	1953 - 1965	Schramm, et al., 1967 Action, UNESCO, IIEP, 1967
Rationale for Using Medium	**Length/Frequency of Lessons**	**Grades/Subjects**
To offer instruction in subjects where schools had limited abilities to provide To impart desired social values	562 hours per year	Music: Grades 1-2; 3-4 Social Studies: Grades 1-2; 3-4 English as Second Language: Grades 5, 6 & 7 and Forms I, II, and III of secondary school; A children's lunch hour program: 30 minutes of educational material and entertainment broadcast every day of the school year
Target Population	**Language of Instruction**	**Instructional Method**
Primary and secondary school and teachers	Thai/English	Varied according to subject Dramatic scripts used in social studies Active methods used for English and music

Teacher Role	Teacher Preparation	Teacher Background	Acceptability
Teacher expected to prepare students for broadcasts, lead students responses, review materials and conduct post-broadcast activities	30 minute teachers program twice each week of the school year A summer course to prepare teachers to use the English radio broadcasts	No information	Many older teachers unfavorable at first. Attitudes believed to have improved during second and third years but deteriorated again because of "growing difficulty in receiving signal from Bangkok. Parents and pupils attitudes were positive

Other Materials Used	Major Management Issues	Major Operational Issues
Scripts and notes printed and circulated to teachers	It was difficult to fit a tight broadcast schedule to widely varying time-tables of schools	Financial and foreign exchange impeded development of program quality and expansion of the system. Reception of signals became harder as more commercial stations began broadcasting. Maintenance of sets a problem for many schools. Co-operation of teachers was often a problem

Effectiveness	Internal Efficiency	Equity
In comparisons between radio and control students, in social studies, differences in favor of the radio students were clear in grade 3, and less so in grade 2. In music differences in favor of radio students were highly significant in written tests and tests of dancing and singing. In English, there were no significant differences apart from writing abilities at Grade 6 (in favor of control students) and at Grade 7 (in favor of radio students)	No information reported on the various indicators of internal efficiency apart from student achievement	No information

External Efficiency	Costs
No information	Annual expenditures for the educational broadcasts have been less than 0.2% of the Ministry budget. The cost per pupil of serving the 20% of Thai pupils who received the broadcasts comes to about 0.5% of the total expenditure per pupil on education. This breaks down to a cost of about 2 cents per student-hour

Sustained/Replicated/Expanded	Comments
Thailand continues to use educational radio for primary education and adapted the Nicaraguan Radio Math lessons	

Intervention

Tarahumara Radio Schools

Medium

Radio

Coverage

1081 pupils in 46 schools (1971)

Country/Region

Mexico (Sierra Tarahumara, a remote region in Chihuahua state.)

Years Being Reviewed

1957-72

Studies Providing Data

Schmelkes de Sotelo (1972; 1977); Jamison & McAnany (1978)

Rationale for Using Medium

Extending schooling to remote communities where it was impossible to establish an "official" school

Providing instruction of sufficient quality to ensure continuation in regular schools

Grades/Subjects

Grades 1-4 (generally functioning as a multigrade classroom) Subjects: reading, arithmetic/geometry, history, geography, science, civics, art, and hygiene

Length/Frequency of Lessons

15 minute broadcasts, followed by 45 minutes of exercises throughout the day, daily

Target Population

Originally intended for the Tarahumara Indians but included white children as well

Language of Instruction

Spanish (although the majority of Tarahumara families speak no Spanish)

Instructional Method

Almost literal reading of material from official textbooks by radio teacher

Teacher Role

One or two "auxiliary" teachers interacting with radio teacher, but frequently provided instruction in lieu of radio

Teacher Preparation

Not reported

Teacher Background

Teacher subject matter knowledge or attendance at summer courses did not affect pupil achievement

Acceptability

Not reported

Other Materials Used

Official school textbooks distributed free to pupils

Major Operational Issues

Bad reception and difficulty obtaining repairs and batteries

Evaluation found only 7 of 24 schools visited actually making use of radios

Major Management Issues

Rapid expansion of system beyond administrative capacity of the system resulted little planning or supervision of schools

System possessed little experience in use media

Effectiveness

Fourth grade pupils in 1971 scored 60.1% on third grade exams in arithmetic and Spanish compared to 55.1% for pupils from Class C private schools in Mexico City on the same tests

Internal Efficiency

Between 1957-71, interyear dropouts were 85% (national mean of 72% for rural schools); estimates suggest as many as 23% of dropouts resulted from school closing

Dropouts increase at higher grades, suggesting higher opportunity costs

No data on failure in school

Equity

Students ethnic background was significant ($p<.01$) predictor of overall academic performance with white pupils outperforming Tarahumara pupils (but not in arithmetic); these differences increase between first and second grade

Tarahumaras more likely to dropout and are underrepresented in grades 3 and 4

External Efficiency

Little hard data. Evaluation concludes that pupils who complete fourth grade are prepared to continue in regular schools

Evaluation suggests that instruction not suited to the social and economic milieu and notes that while graduates do not use what is learned in school, some graduates use school knowledge to "exploit their people" and that "many" find work in towns and cities

Sustained/Replicated/Expanded

Radio schools began in 1955. Radio was no longer used after the 1973-74 school year

Costs

Total instructional and administrative costs (1969-70) per student was about $90. This compares to an estimated per pupil primary expenditure of $62 in Mexico in 1970. Jamison & McAnany estimate for 1972 an average annual per student cost of $52.86 (or $.331 per hour) based upon 1081 students

Comments

The use of radio to extend primary education gave way to efforts to promote the use of radio for community education inspired by Paulo Freire

Intervention

Mexican Radioprimaria

Medium

Radio

Coverage

2075 pupils in 65 schools (1975)

Country/Region

Mexico (Region around San Luis Potosi - 260 miles northwest of the capital)

Years Being Reviewed

1970-72
1975 update

Studies Providing Data

Spain (1977); Jamison & McAnany (1978)

Rationale for Using Medium

To increase efficiency of rural schools by running a six grade school with four teachers

To reach school dropouts (never implemented)

Grades/Subjects

Grades 4-6: Spanish, arithmetic, history, geography; also some physical education, nature study, and practical activities

Length/Frequency of Lessons

Five or six fourteen minute broadcasts each day, most of them multigrade format

Target Population

Rural children
(no ethnic distinctions reported)

Language of Instruction

Spanish

Instructional Method

Little information, but indications that broadcasts followed closely lessons in official textbooks

In 1975, lesson formats said to rely less on direct teacher talk, more dramatizations and concrete examples provided

Teacher Role

Little information: reported that only 10% of teachers felt they gave up any authority because of radio

Teacher Preparation

No orientation provided; high rate of teacher turnover

Teacher Background

Appear to have normal school education; 78% of teachers working in the area live in the city and commute to to rural schools

Acceptability

48% of teachers felt using radio as an aid superior to direct teaching alone; 46% said it was not

Other Materials Used

Mimeographed biweekly guides for teachers; free textbooks for pupils

In 1975 pupils received supplementary materials

Major Operational Issues

Poor reception in many areas

Only 18 of 44 schools found to have audible, functioning radio

Major Management Issues

Inadequate mechanisms for management and supervision of schools

Effectiveness

Achievement tests in arithmetic and Spanish given three months apart to radio and non-radio sixth graders; gain scores in means on Spanish for radio pupils (3.7) significantly better than for nonradio pupils (2.3); on arithmetic radio pupils also outperformed nonradio pupils 3.3 to 2.9 gains on mean but not significant

Internal Efficiency

No conclusions can be drawn about effects of radio on repetition or dropout

Teacher and pupil attendance appeared good in radio schools

In 1972, 36 of 44 radio schools were already complete schools and used radio as supplement, not to improve efficiency

Equity

No conclusions can be drawn about any differential effects of using radio with particular groups of pupils

Large proportion of schools that already had sixth grade suggests groups less in need of new technology benefitting more

External Efficiency

Interviews with parents indicate widespread perception that primary education has little utility in rural areas

Interviews with representatives of local industry pointed to difficulty in finding work with only primary school education

A 1972 survey of 207 graduates of primary schools in area found 35% of graduates working and 35% continuing studies but no comparisons of radio and nonradio schools were made

Costs

Jamison & McAnany (1978) compute an average annual cost of $16.44 per student ($.068 perhour) based upon participation of 2800 students

Sustained/Replicated/Expanded

Decline in number of schools using radio from 49 in 1970-71 to 37 in 1973-74. This increased to 65 in 1975 but at this time radio was used only in fifth grade classes

Comments

Intervention	Medium	Coverage
Nicaraguan Radio Mathematics Project	Radio	3,000-4000 pupils at onset of project, rising to 10,000 pupils in participating schools (unknown number listeners in other schools and at home)

Country/Region	Years Being Reviewed	Studies Providing Data
Nicaragua Corazo and Rio San Juan provinces	1975-1978	Suppes, Searle, and Friend (1978); Friend, Searle, and Suppes (1980); Friend (1985); Friend, Galda and Searle (undated); Jamison and McAnany (1978)

Rationale for Using Medium	Grades/Subjects	Length/Frequency of Lessons
Improve educational quality by replacing existing instruction with radio instruction (Project goals was to devise and demonstrate a method of effective and affordable radio instruction that could be used in any developing country)	Mathematics Grades 1-4	27 minute lessons, 5 days per week followed by 20-30 minutes of post-broadcast activities

Target Population	Language of Instruction	Instructional Method
Rural and urban children	Spanish	Project laid foundation for the "interactive" radio mode. Features included active and frequent pupil responses, immediate reinforcement, distributed practice with "segmented" structure (about a dozen topics presented per lesson); lessons used numerous examples, controlled vocabulary, flavor of "guided discovery," and ongoing formative evaluation of lessons

Teacher Role	Teacher Preparation	Teacher Background	Acceptability
Radio delivers the daily lessons, teachers conduct post-broadcast activities	Three hour training session each year. Teachers given a guide but no regular supervision	Teachers had an average 11 years of education, teacher's knowledge of math judged to be weak	A survey of participating teachers (Tilson and Searle 1978) reports teachers found radio lessons help children learn and are helpful for themselves. They also expressed a concern that radio lessons could not be adjusted to the different abilities of children

Other Materials Used	Major Operational Issues	Major Management Issues
Worksheets used for Grade 1. Grades 2-4 used inexpensive notebooks. Sparing use of other supplementary materials	Multigrade classrooms (50% of total) presented problems	

Effectiveness	Internal Efficiency	Equity
Radio classes outperformed control classes in all grades. Differences were unusually strong in grade one. Effect sizes are as follows: Grade 1: 1.32; Grade 2: .28; Grade 3: .47; Grade 4: .02	The use of radio did not have strong positive effects on attendance, dropout, or repetition	Urban radio children outperformed rural radio children. No significant differences attributable to gender

External Efficiency	Costs
No information	Assuming system were expanded to 120,000 users and including per student fixed cost allocation, Jamison and McAnany (1978) calculate cost to be $3.05 per student per hour. Marginal costs (cost of adding one more student to the system) were $1.64

Sustained/Replicated/Expanded

At the termination of AID assistance, planning was under way to expand geographic coverage of the project and for developing lessons for Grade 5. These were headed off by the culmination of the revolution in 1979

Intervention

Kenya Radio Language Arts Project

Medium

Radio
(series English in Action)

Sample

3908 pupils in 21 schools
(including control groups)

Country/Region

Kenya - Seven districts selected to permit a national sample representative of different national language groups

Years Being Reviewed

1981-84

Studies Providing Data

Oxford et al. (1986), Christensen (1985), and Friend & Kemmerer (1985)

Rationale for Using Medium

To teach English as a second language more effectively (Project goals was to compare effects of radio instruction with conventional instruction)

Grades/Subjects

English - Grades 1-3

Length/Frequency of Lessons

30 minutes, 5 days per week

Target Population

Rural children:
eight different mother tongues

Language of Instruction

English

Instructional Method

Version of the interactive radio model - used open-ended pupil competencies, active participation, immediate reinforcement, distributed practice; formative evaluation

Teacher Role

Provide mother tongue translations as needed, provide some corrections to students, conduct postbroadcast activities

Teacher Preparation

Teacher Background

Teachers' average age was 32, with 10 years of education and 9 years experience

Acceptability

80% of teachers/ headmasters indicated radio was very useful; 64% teachers thought overall English ability of radio pupils better than other pupils

Other Materials Used

Pupil worksheets bound in booklets

Major Operational Issues

Radio reception "problematic" in 18% of schools and "poor" in 3%. One district expressed difficulty obtaining printed materials on time

Major Management Issues

Inter-year teacher turnover occurred in a large minority of classes

Effectiveness

Radio pupils outperformed non-radio pupils on all tests, differences nearly always statistically significant. Largest differences occurred in listening skills. Effect sizes as follows:

	Grade1	Grade2	Grade3
Listening	.89	1.17	.37
Reading	.32	.29	.45
Writing		.22	.29
Speaking			
(Word Total)		.23	.15
(Meaning)		.39	.49
(Grammar)		.31	.54

Internal Efficiency

Three times as much content presented in half hour blocks of instruction compared with conventional instruction

Less disruptive pupil behavior observed in radio classes

Repeaters and transfers into radio classes appeared to have some difficulty "catching up"

Equity

Socio-economic factors related to pupil performance were not assessed

The only variable found to affect pupil performance was "district." The underlying variable within district appeared to be "years of teaching experience"

External Efficiency

No data reported on success of radio students in school after grade 3 but readiness of radio pupils to continue in English language instruction after grade 3 indicated by 90% of teachers

Costs

Estimate of future annual per pupil recurrent costs projected for implementation in all primary schools in Kenya provided by Friend & Kemmerer, 1985. Assumes radios last 5 years, 3 sets of batteries per radio per year, use of existing radio channels. Cost per pupil (including transmission costs, teacher training and manual, batteries, radio and maintenance, and some program costs) $.34

Sustained/Replicated/Expanded

The Ministry of Education of Kenya decided not to continue English in Action after 1985

Comments

Intervention	Medium	Coverage
Basic Skills Pilot Project (Mathematics Component)	Radio	In 1983, 50 schools in 5 provinces

Country/Region	Years Being Reviewed	Studies Providing Data
Thailand	1981 - 1983	Galda (1985); San-jan (1982); Friend, Galda and Searle (1979)

Rationale for Using Medium	Grades/Subjects	Length/Frequency of Lessons
-Improve quality of instruction, especially where teachers are undertrained -Reduce regional inequities in educational opportunities	1 - 3 Thai language/ mathematics	Daily - 25 minute broadcast and 15 minute post-broadcast activity

Target Population	Language of Instruction	Instructional Method
School children throughout the country	Thai	The Nicaraguan Radio Math lessons were adapted for Thailand

Teacher Role	Teacher Preparation	Teacher Background	Acceptability
Teachers expected to observe and help students during radio lessons and in a few cases may spend time teaching another class. Teacher lead post-broadcast activities	Two-day workshop	No information	Questionnaires indicated high degree of enthusiasm on part of teachers and headmasters

Other Materials Used	Major Operational Issues	Major Management Issues
Teacher's guide; student's notebooks; student workbooks in grade 1	No information	No information

Effectiveness	Internal Efficiency	Equity
Radio students outperformed control students in all regions for three years. In a 1981 comparison of achievement of second graders, differences in achievement in the Northeast had an effect size of .58 and .24 in the Central Plain (Bangkok area). This compared with .36 for a similar comparison in Nicaragua	Some evidence that radio helped improve discipline and punctuality on part of teachers and students	In a 1981 comparison between second grade children in the more advantaged Central Plain region and the disadvantaged Northeast region, achievement levels rose in both regions and achievement disparities between two regions was nearly overcome

External Efficiency	Costs
No information	Estimates of future annual per pupil recurrent costs for implementation in 30,693 schools (1,081,733 pupils) provided by Development Communication Report (Spring 1985). Assumes radios last 5 years, 34% of schools have electricity and batteries last for 100 hours. Cost per pupil (including non-reusable workbooks and teacher manuals and excluding teacher orientation) $.44.

Sustained/Replicated/Expanded	Comments
Although it appears that original goal of expanding to all 30,000 schools has not yet been achieved, project is ongoing	

Intervention	Medium	Coverage
Radio-assisted Community Basic Education (RADECO)	Radio	By 1986, 65 centers with 1117 children
Country/Region	**Years Being Reviewed**	**Studies Providing Data**
Dominican Republic - Province of Barahona in the Southwest Region	1983 - 1986	Walker (1986), Hanesen, Kozlow and Olsen (1983), Sanguinetty (1985), Friend & Kozlow (1985), Friend (1984), Helwig & Friend (1985) Moxeng (personal communication)
Rationale for Using Medium	**Grades/Subjects**	**Length/Frequency of Lessons**
To provide primary education to children in rural areas where there are no schools	1 to 4 - Mathematics and language with segments of social science, natural science, civic education, and physical education woven into the lessons.	One hour per day
Target Population	**Language of Instruction**	**Instructional Method**
Children 7 - 14 who do not have access to schools	Spanish	Derivation of the interactive radio instruction model. Math lessons were adapted from the Nicaraguan Radio Math Project
Teacher Role	**Teacher Preparation**	**Teacher Background** **Acceptability**
Uses paraprofessional monitors to take charge of makeshift radio "schools." All instruction is provided by the radio	An orientation course lasting a few days	Monitors are expected to be literate with 6 - 9 years of schooling; most had a minimum of 3rd grade
Other Materials Used	**Major Operational Issues**	**Major Management Issues**
Worksheets	Delays have been encountered in delivering and collecting worksheets. Logistical difficulties in providing regular supervision of radio schools	Coordination of the functions in the Santo Domingo office (technical, curriculum design, preparation of materials) and those of the Barahona office (supervision of the communities, training of the monitors) has posed problems
Effectiveness	**Internal Efficiency**	**Equity**
Evaluation activities are ongoing and being taken over by host country. Evidence so far suggests that when compared to conventional schools in the same region, the RADECO instruction in math is superior and in reading nearly as good	Absenteeism of 33% in some places. However, evidence that children may be learning at least as well as students in regular schools but at half the price is highly indicative of internal efficency	(a) Project has provided education and promoted social integration of children of Haitian immigrants. (b) Evidence that some students leave regular schools for RADECO schools suggests success in not becoming an inequitable inferior track of rural education
External Efficiency	**Costs**	
Too early to evaluate. First cohort will finish grade 4 in November, 1986. Plans have been made to allow students to take a "challenge" exam which would permit placement in conventional schools	Annual cost per pupil was about half the cost of a year of conventional primary school instruction	
Sustained/Replicated/Expanded	**Comments**	
Good possibility that the project will be expanded to include the Northwest Region and adapted for other countries		

reported in the literature: the Paraguay Rural Radio Education Project and the Shuar Radio Schools of Ecuador. (Information on these initiatives was not complete enough to allow us to prepare detailed summaries.)

The Shuar Radio Schools aimed at providing more relevant and culturally sensitive education to the school children of the Shuar Indians of Ecuador. (The information on these schools is drawn from the Clearinghouse on Development Communication's [1982] Project Profiles, p.39-40). The few Shuars who had been trained as teachers were used as radio teachers, and other Shuars were used as paraprofessionals. Enrollments in the Shuar Radio Schools grew from 486 (1972-73) to 3100 (1978). The Radio Schools demonstrated high pass rates, which declined somewhat with expansion of the system from 97.4% (1972-73) to 84.5% (1976-77). The Radio Schools also apparently reduced the drop-out rate from 30% in the conventional schools that were replaced to a level described as "minimal."

As of 1986, according to the Ministry of Education in Ecuador, the Shuar Radio Schools continue to operate.

The Rural Radio Education Project in Paraguay was an unsuccessful attempt in the 1970s to apply radio to the task of delivering primary education (to adults as well as children) in rural areas. According to the Clearinghouse on Development Communication (Project Profiles, 1982), the project, like the Shuar Radio Schools, took a bilingual approach and attempted to develop a route for rural children and adults to obtain a complete primary education. The project was terminated when AID funding ended.

The major breakthrough in the use of radio for primary education also took place during the 1970s. This was the Radio Mathematics Project in Nicaragua, sponsored by USAID and undertaken by Stanford University's Institute for Mathematical Studies in the Social Sciences. This effort laid the groundwork for later applications of radio that would come to be called "interactive radio."

The model for radio instruction developed in Nicaragua (this and the other interactive radio cases are outlined on the following pages) applied empirically-validated techniques for developing and testing radio lessons. Radio was used for direct instruction and not curriculum enrichment. What was distinctive about the approach in Nicaragua was the conversational form followed by the radio teacher, who would elicit several oral responses (often 100 per half hour lesson) from students in the radio classroom. Although the instruction provided by the radio was essentially one-way, the frequent student responses and feedback provided in anticipation of these responses by the radio teacher is arguably a form of interaction. Paisley and Chen

(1983, p.9) define interactivity as the ratio of user activity to system activity. By this criterion, the interactive model does appear to distinguish itself from other applications of radio to primary education in developing countries.

The Nicaraguan effort and the subsequent Radio Language Arts Project in Kenya, the Thai Basic Skills Pilot Project, and the Radio Language and Radio-Assisted Community Basic Education (RADECO) Project in the Dominican Republic constitute a concentrated effort to explore the effects of a single instructional medium focused on the early years of primary school across several subjects and countries. The cases, which are summarized on the preceding pages, have been rich in information and provide the best empirical evidence to date of radio's effectiveness as an instructional tool in primary education in developing countries. (The Nicaragua experience is described in Suppes, Searle, and Friend, 1978; Friend, Searle, and Suppes, 1980; Friend, 1985; the Kenya experience is described in Oxford et al., 1986; Christensen, 1985; Friend and Kemmerer, 1985; the Thailand experience is described in Galda, 1985; Friend, Galda, and Searle, 1979; and Sang-jan, 1982; the RADECO experience is described in Hanssen, Kozlow, and Olsen, 1983; Helwig and Friend, 1985; Friend, 1984; Sanguinetty, 1985; Walker, 1986; the interactive model is also discussed in Block, 1985; Searle, 1985.)

Radio lessons for primary school science following the interactive radio model are to be developed and tested in Papua New Guinea during the next few years. There will also be replications or adaptations of the interactive radio model in other countries during the next few years under AID's Radio Learning Project.

If the interactive radio experience is well-documented, the same cannot be said for educational radio as a whole in developing countries. Hawkridge and Robinson (1982) mention that, "Almost every country claims to use educational radio or educational television or both." UNESCO (1984), in reporting statistical data collected from member states, indicates the number of hours of radio broadcasting "devoted to a specific curriculum." However, it is not reported how much of this is for education at different levels. So, for the majority of developing countries, we really do not know how radio is being used in primary education and with what consequences.

Summary of Results

In this section, we summarize the outcomes of the radio case studies under the headings of instructional management, content, instructional materials, operational outcomes, equity, effectiveness, internal efficiency, external efficiency, sustainability, and costs.

Instructional Management. Our interest here is in how radio, when used as an alternative to lessons usually provided by the teacher, fits into the classroom. Numerous issues could be addressed in this connection, but we limit our attention to questions of teacher acceptance of radio use and what new skills are necessary for teachers to use radio.

From our case summaries, it appears that teachers generally accepted the use of radio in the classroom. In Mexico, almost half the Radioprimaria teachers expressed the belief that using radio as an aid to instruction was superior to direct teaching alone. Teachers' acceptance of radio was also positive in Nicaragua, Kenya, and Thailand.

The use of radio required teachers to play a new instructional role. In all the cases we studied, responsibility for direct instruction was taken from the classroom teacher and assigned to the radio teacher. The classroom teacher was expected to prepare children for broadcasts, distribute accompanying materials, and provide help during the lessons. In many cases, there were postbroadcast activities for the teacher to conduct.

Where we have information, we find that teachers were prepared to undertake these tasks in anywhere from three hours (Nicaragua) to three days (Thailand and the Dominican Republic). We found that this preparation worked even though the educational background of teachers usually was weak (10 to 11 years of schooling in Kenya and Nicaragua or a very weak 3 to 9 years in the Dominican Republic).

A final question related to instructional management: Did the use of radio in one subject lead to improved teaching in other subjects? This has not received a good deal of explicit attention in the literature. It is often unclear what is expected to transfer--possibly a modeling of more active methods and the use of reinforcement.

We do find some evidence of teachers expressing the view that the use of radio has helped them become better teachers. Perhaps a more important question is whether it is really desirable for a teacher to model classroom instruction on radio instruction. Friend (1980, p.xviii) puts it this way:

> Do teachers learn new pedagogical techniques from radio? (We have some anecdotal and observational evidence that they do, but the techniques they learn are sometimes imitations of techniques that are well-suited to radio but not ideal for human teachers.)

Content. Radio has been used to teach almost all school

subjects offered at the primary level. From the different cases we looked at, which permit a limited number of comparisons, we might tentatively conclude that radio seems to be most successful in teaching mathematics. The evidence from Kenya strongly suggests, perhaps not surprisingly, that radio is a good means for teaching language-learning and listening skills. So far, teaching reading by radio seems more difficult than teaching mathematics. No conclusions can be drawn about subjects like science and social science without tests similar to the ones in Nicaragua and Kenya.

With respect to using radio at different grade levels, most of the information we found came from applications at the early primary level. We do not know whether radio, especially the interactive model, would be equally effective after the fourth grade.

Instructional Materials. A question of great practical significance but one that is not easily answered is whether radio lessons can effectively substitute for more expensive printed materials like textbooks. Rarely do circumstances permit valid comparisons to be made between the use of radio and textbooks. The one comparison we did find was in Nicaragua (Jamison, Searle, Galda, and Heyneman, 1981). Three groups (in different schools) of first graders were compared: one that received radio lessons, one that received textbooks, and one that served as a control group. Although both the radio and textbook interventions showed positive effects on achievement and helped close rural-urban disparities in achievement, radio had a stronger impact. The textbook group scored about .33 of a standard deviation above the control group; the radio group scored 1.5 standard deviations above the control group. We wonder why more comparisons of this kind have not been attempted.

It should be noted that the use of radio is not necessarily a substitute for using printed materials. We found no instances where radio was used without supporting printed materials. In Nicaragua, however, substantial cost reductions were obtained, after grade one, by doing without student worksheets (exercises were copied into notebooks).

Operational Outcomes. Many operational problems associated with using radio were noted. We found that obtaining batteries and keeping radios in good repair posed problems in most of the cases we examined. Reception of clear signals was difficult in many schools in Kenya, Mexico, and in the early radio project in Thailand. Multiple grade classrooms posed problems in Nicaragua.

Clearly, such difficulties can lead to a substantial loss of instruction during the school year. What cannot be answered is what level of instructional loss schools are likely to tolerate. We can only speculate that for radio instruction to be viewed as

an acceptable and reliable deliverer of instruction, the instructional loss coming about because of poor physical facilities and other operating conditions must be considerably less than what is routinely lost through such things as teacher absenteeism. A teacher missing school for twenty days a year might well be regarded as normal. Conversely, missing ten radio lessons per year may be regarded as making radio unreliable. The Radio Math Project in Nicaragua, however, showed that it was possible to address the issue of missed lessons (because of not receiving broadcasts or absenteeism) by using redundancy throughout the sequence of radio lessons.

Equity. In all the cases we examined, radio was used (although not exclusively) to reach children in rural areas where educational opportunities were judged to be inferior to those in urban areas. In two cases, the Shuar and Tarahumara Radio Schools, radio was used to reach disadvantaged sub-populations. The Shuar schools appear to have succeeded in making education more relevant to the community. The Tarahumara schools failed to reduce the gap in achievement between Indian and non-Indian students. In the Dominican Republic, RADECO reached rural students who for economic and geographical reasons were unable to attend conventional schools.

In Thailand and Nicaragua, we found, as might be expected, that urban radio pupils outperformed their rural counterparts. In Thailand, existing disparities in achievement levels in mathematics were narrowed as a result of radio instruction.

The available evidence (Kenya and Nicaragua) suggests that boys and girls learn equally well from radio.

While we see in some cases that the use of radio in primary education contributed to improved equity and that in other cases it did not, we found little information about radio's relationship to specific aspects of family or community life.

Effectiveness. There appears little doubt that radio, when used properly, can be an effective means for improving student achievement in a variety of school subjects.

Thailand's experience in the 1960s demonstrated that radio could be used effectively to enrich the school curriculum. In comparison with control students, radio students showed positive differences for achievement in music, mixed results for social studies, and no real differences in English.

In the two Mexican studies, we also found positive learning effects, although it was not entirely certain that these could be attributable to the radio lessons.

For the interactive radio interventions, the impact of radio

on student achievement is impressive. From effect sizes reported in our project summary sheets for the grade/subject/skills tested, we compare average effect sizes from each of these interventions in the table below.

Intervention		Average Effect Size	Raises Mean From...
Nicaragua		.52	50th to 70th percentile
Kenya		.45	50th to 67th percentile
Thailand			
	Urban	.24	50th to 59th percentile
	Rural	.58	50th to 72nd percentile

We find a large average effect size of .52 across four grades for mathematics instruction in Nicaragua. If we did not include the results from grade 4, when the school year coincided with the onset of the revolution, this would rise to .69. For Kenya, we also find a high average effect size across three grades in listening, reading, speaking, and writing skills. In Thailand, effect sizes range from a modest .24 for mathematics instruction among second graders in the area of Bangkok to .58 in the rural Northeast. (It should be kept in mind that differences in effect size refer to the size of gains and not to absolute levels of achievement.) We were not able to calculate effect sizes for RADECO in the Dominican Republic. The fact that there are no differences between the hour long daily radio intervention in an out-of-school setting and a conventional day of school instruction is indicative of success.

We found little or no information about radio's effectiveness on outcomes other than achievement.

Internal Efficiency. We are interested in whether radio contributes to internal efficiency (apart from student achievement) in the delivery of primary education in developing countries. Our judgments regarding internal efficiency are based upon changes in indicators such as school dropout rates, repetition rates, and the number of children being reached by the educational system or the quality of education being delivered for a given amount of resources.

There is evidence that radio contributes to internal efficiency. The use of radio in Kenya made it possible to

deliver three times as much content in a half hour block of time as was delivered through conventional instruction (Oxford et al., 1986). Teacher and student attendance appeared to be improved in the Mexican Radioprimaria classes (Spain, 1977). Teacher and student punctuality were positively affected by radio in Thailand (Galda, 1985).

Except for the positive experience of the Shuar Radio Schools in Ecuador (Clearinghouse on Development Communications, 1982), we were unable to find any evidence that radio reduced dropout rates.

The Mexican Radioprimaria's attempt to achieve efficiency by using radio to "complete" a school by offering six grades of instruction with four teachers was unsuccessful. Most schools that ended up using the radio lessons already were complete schools (Spain, 1977).

We found no evidence that radio reduced repetition rates. This was especially disappointing in the case of Nicaragua, where as Jamison and McAnany (1978, p.109) observed:

> ...it is perhaps well worth noting that, even though the cost per student is relatively high, adoption of the RMP (Radio Mathematics Project) would almost surely reduce costs per graduate because of the effect it has on reducing repetition rates.

Unfortunately, this hoped-for improvement was not realized. It was learned in Nicaragua that repetition is only partly related to student performance (George, 1980; Galda and Gonzalez, 1980; Jamison, 1980).

Perhaps the best example of radio's potential for increasing internal efficiency in primary education is the case of RADECO in the Dominican Republic. The evidence currently available suggests students perform at least as well on math and reading tests as students do in conventional schools in the region, but with <u>about half the time spent in learning at about half the cost</u> (Friend and Kozlow, 1985; Sanguinetty, 1985). Although we are not comparing full or identical sets of educational outcomes--indeed, Friend and Kozlow (1985) note that no comparisons were made in science and social science and that conventional schools aim at a wider range of outcomes than RADECO schools--the RADECO results are nonetheless impressive.

<u>External Efficiency</u>. We found almost no information that allows us to evaluate radio's contribution to the external efficiency of primary education in developing countries. This is not surprising, since, in most countries, little empirical attention is given to the relationship of primary education to the employment or the continuation in education of primary school

dropouts. Few of the radio interventions that we examined lasted long enough or had the necessary resources to look at the longer term success in school or in employment of students who had been taught by radio. We mentioned earlier that it would be very hard to presume that exposure to a half hour broadcast in what might have been one school subject during the course of a few years is likely to have a discernible effect later in life. However, the RADECO experience in the Dominican Republic, where radio carries virtually the entire instructional load, may offer a good opportunity for examining the external efficiency of radio instruction.

Sustainability. We found that among the cases we examined, there was mixed success for radio instruction moving from an experimental or demonstration phase to a sustained or expanded role in national educational policies. One of the most promising demonstrations of instructional radio, the Nicaraguan Radio Mathematics Project, was abandoned following the overthrow of Somoza. The Radio Language Arts Project in Kenya was discontinued after a successful pilot phase. Radio efforts in Mexico were abandoned as was one in Paraguay (although apparently for reasons unrelated to radio). On the other hand, the Dominican Republic is apparently moving forward to extend RADECO. The Shuar Radio Schools, as best we can tell, are continuing to flourish. In Thailand, supplemental radio has enjoyed sustained application for more than two decades, and the use of direct instruction radio lessons adapted from Nicaragua may one day be used on a large scale.

Costs. What does it cost developing countries to use radio to improve the quality of instruction in one or more subjects? We believe that the evidence shows that it costs either a little or a lot. Whether radio is expensive or cheap depends to a large extent on whether one assigns fixed capital costs for developing radio lessons to the annual per student costs, to the number of students served by radio instruction, to other assumptions made in the calculation, or to how incremental, annual per student costs relate to the country's annual overall expenditures for primary education.

The costs of radio appear to be most attractive for a developing country when a successful pilot program has been completed and the costs of instructional development have been paid by a donor. No new lessons need to be developed, and there are no new transmission facilities required to broadcast across the country. There are large numbers of students to be served and the fixed capital costs for instructional development (paid by the donor) will not be added to the calculation of average annual per student cost in order to arrive at an estimation of "true costs" to society. Subject to the assumptions mentioned in our project summary sheets, annual per student costs were found to be $.34 and $.44 for Kenya (Friend and Kemmerer, 1985) and

Thailand, respectively (Development Communications Report, 1985). Again, these are based on a projection of large numbers of students to be served (about one million).

The annual per student costs will not be so low when there are fewer students, when the capital costs of instructional development are added, or when new broadcasting capacity must be developed to add new grades or reach new regions. Jamison and McAnany (1978) estimate the costs of the Nicaraguan Radio Math Project, which they regard as expensive, to be $3.05 per student per year. This figure was based on 120,000 students being served and includes a per-student allocation of fixed capital costs for instructional development. This is what instructional radio could cost a country unable to secure financial assistance from a donor to cover capital costs. When per-student allocations of fixed costs are not included, the actual costs to the country approach the marginal cost (the cost of adding one more student), which, for Nicaragua, was $1.64 per student (Jamison and McAnany, 1978).

The costs of the other cases we examined varied widely. Thailand during the 1960s, with 800,000 students being served, showed annual per student costs of $.44 (Jamison and McAnany, 1978). In the Mexican cases, where radio was being used for small numbers of students (1,000 to 1,800), the annual per student costs for the Tarahumara Radio Schools were $52.86, and for Radioprimaria, $16.44 (Jamison and McAnany, 1978).

Although annual per student costs are useful for purposes of analysis and comparison they must also be viewed in the aggregate sense relative to yearly educational budgets. For example, a cost of $.44 per student might appear to be very low. But when this is multiplied by a million students, officials in ministries of education and finance must face adding $440,000 to the annual recurrent educational budget for improvement in one subject. This may not appear attractive if the alternative is, say, making a fixed investment in improving textbooks and passing on recurrent costs to parents.

Conclusions

The evidence suggests that radio can and has played a positive role in the production of learning in primary schools in developing countries. We reach this conclusion on the basis of eight cases from seven countries, in which one model of radio instruction is overrepresented.

We find that radio has not been fully exploited as an instrument of mass communications in the delivery of primary instruction on a national scale, except in the case of Thailand. In most of the cases reviewed, radio has been used with audiences of about 1,000 - 4,000 students. Similarly, we find that radio

has been used mostly to improve the quality of instruction in one or more subjects and not, except in the Dominican Republic, as a means to extend educational opportunities to those not served by schools. The evidence suggests a generally high degree of teacher acceptance and that teachers can learn to work with radio instruction with relatively little training. We found that radio lessons were almost always supported by printed materials. Receiving broadcast signals, keeping radios in repair and supplied with batteries, and getting such things as printed supporting materials to schools on time represented considerable operational and management challenges.

Because of lack of evidence, we were unable to conclude that radio has had an effect on the external efficiency of primary education in developing countries. The evidence that is available suggests that radio, apart from its effects in raising student achievement, has had mixed results in affecting other aspects of the internal efficiency of education.

We learned that radio instruction in a school subject can be delivered to children in schools for about the cost of a textbook, between about $.40 and $3 per student per year, depending on assumptions and conditions.

At least for the interactive radio cases, the evidence suggests that radio can have a strong impact on student achievement. In view of this evidence, we must ask why more countries have not adopted the interactive model. Questions that must be asked should include the following:

- Has the case for textbook availability been made so persuasively as to overwhelm the likelihood of consideration of other instructional possibilities?
- Does a general resistance to the use of instructional hardware in education in developing countries preclude consideration of radio?
- Are the transmission and reception of radio signals regarded as simply too unreliable for using radio to deliver instruction?
- Are the recurrent costs of using radio to deliver primary instruction perceived as too high?
- Is the effort to reorganize instruction and manage a radio delivery system regarded as too burdensome?

The use of radio has been endorsed widely and at all levels of the international community as offering an appropriate, effective, and affordable means for improving education in developing countries. To a large extent, its potential has been demonstrated. Yet it appears that developing countries have not made as much use of radio in primary education as one might expect. It is important that we learn why.

Radio as a Policy Option. We believe that the literature just reviewed points to several key questions that educational policy makers in developing countries should ask when considering the possible use of radio to extend or improve primary education. They are the following:

- Radio offers both the advantages and disadvantages of what might be described as a "centralized" curriculum. Broadcasts come from a fixed point at a fixed time; the content, language, and "culture" of the lessons are not subject to much variation or control at the local level. Therefore, the question to be asked is : Do national conditions permit using a centralized curriculum such as could be offered by radio?

- Are there adequate facilities and resources to ensure satisfactory transmission and reception of broadcasts in the areas to be served? Would this be true beyond the stage of what might be a preliminary pilot project? Does local broadcasting capacity permit adding new grades and subjects?

- Is there likely to be resistance from the stakeholders in the "curriculum status quo"--textbook writers and publishers, local curriculum specialists, teacher trainers, or expatriate educational advisers? How might this resistance be overcome?

- While there is evidence that high quality radio lessons are often more effective than conventional instruction, mediocre radio lessons might be less effective than mediocre conventional instruction. Therefore, the question to be asked is: Is there sufficient high calibre staff to develop, produce, and deliver high quality radio lessons? Would there be a willingness, as there was in Thailand, to offset some of the fixed capital for developing high quality radio lessons by

adapting lessons that have proved to be successful in other countries?

- What will be the "add on" costs to the annual budget and how will they be financed?

2. Television

When developing countries have turned to instructional hardware to lead the way in major efforts to expand or improve education, they have turned to television. Although radio has been recognized as the most universal means of mass communication available to developing countries, we observed in the preceding section that most nations have so far failed to fully exploit radio's potential for reaching large numbers of children. This is not so with television. Where experiments with radio typically involved 1,000 to 4,000 students, experiments with television have reached school audiences of up to a half million.

The television experiments of the sixties and seventies were clearly ambitious, and often linked to a complete reform of part or all of an educational system. The appeal of television and the great expectations that were placed upon it reflected more of an appreciation of television's growing economic and social power in industrialized countries than in any demonstrated instructional capabilities. Indeed, Schramm's (1962) comparisons of instructional television with conventional teaching should hardly have aroused great expectations. Of 421 comparisons, 63 favored television, 50 favored conventional teaching, and 308 showed no differences. The proposition that television can be as good as conventional teaching would be compelling if the strategy called for replacing teachers. But in most of the experiments of the sixties and seventies, television was used for only part of the instructional day, to aid teachers rather than replace them. Before making an investment in a complex and costly undertaking like television, one would want evidence to suggest that television could be a good deal more effective than conventional teaching. We look at the use of instructional television in seven countries--American Samoa, El Salvador, Ivory Coast, Niger, Colombia, India, and Nigeria.

American Samoa

One of the most ambitious attempts to make use of television to improve school instruction took place during the sixties and seventies in American Samoa. (Unless otherwise indicated, information in this section is drawn from Schramm et al., 1981.) Television was chosen as an effective and economical means to forge a complete modernization of primary and secondary school education. The hope was that through a transformation of the educational system with instructional television as the principal delivery vehicle, the academic performance of Samoan students

could be brought to levels equal to those of students in good schools on the U.S. mainland.

The experiment in American Samoa spanned more than fifteen years. It included a reworking of the curriculum. Lessons were developed to cover about 35% of all classroom time. Lessons, which were produced in English, lasted about 8 minutes in the early grades and 25 minutes in the upper grades. Television lessons were accompanied by a packet of curriculum materials, including lesson plans, instructions for the teachers, and supplemental readings.

Advisers from the U.S. took charge of almost all aspects of the educational program. It was recognized late in the experiment that the failure to involve Samoan teachers in the planning and development of instruction and the great haste in moving to cover the entire primary-secondary school curriculum were serious errors.

It was planned that the experiment would not be evaluated until the first cohort had received a complete twelve years of instruction under the new system. Baseline information was not collected. About six years into the project, standardized tests were administered to students in various subjects and at various grade levels. At best, the achievement tests yielded a mixed and inconsistent picture of the effects of student learning on achievement.

Emery (1985, p.498) takes exception with what often has been a generally positive portrayal of the results obtained in American Samoa. She asserts that:

> Results showed that after seven years of expensive concentrated ETV under the most optimal conditions, grades 3-12 achieved 59 per cent of United States norms. This was a drop from the 60 per cent they had been achieving in 1935 when there was only the most 'primitive' oral society teaching by untrained native teachers...
>
> The data scattered through the 'bold experiment' leaves little doubt about two matters (M. Emery, 1984). First, for every subject for which any reasonable baseline data could be established, ETV failed and it failed in direct correlation with grade, or increasing abstraction and conceptualization of knowledge. Second, the senior author (Schramm)...appears to have done everything possible to put the results in the most favorable light. As an example, we have from his Tables 21 and 23 (pages 115 and 116) the fact that there was a 9 per cent decline in oral English scores in Grade 7 after three years with ETV. After

> discussion of the possible reasons for this result, none of which touched upon the failure of television as a teacher, the team concluded that (p.127) 'there is every reason, at least, to think that the standard of English usage improved notably during those years' (i.e. 1964-70). Then, when we examine Table A.II we find in their own figures for the teaching of English that face-to-face teaching is from 16-19 times more effective than television.

The costs of instructional television in American Samoa were high. In 1972, with school enrollments of 8,100, the per student cost (including a share of annualized capital costs) was about $166 per year.

A survey conducted in 1972 found a high degree of acceptance of instructional television among elementary school teachers and administrators, especially for teaching oral English. At the high school level, the use of television was strongly criticized by teachers and students.

In 1970, political winds changed. The incoming Governor to American Samoa described the experiment with instructional television as an "utter and complete failure" (quoted in Schramm et al., 1981, p.80). Opposition to television led to an eventual reduction in its use as teachers were given the authority to decide when and where to use it. In 1974-75, power shortages were encountered throughout the year, and television was not received during the final month of school. By this time, only one channel was being used instead of six (Masland and Masland, 1976). In 1975, the use of television was eliminated entirely at the secondary level.

<u>El Salvador</u>

The use of instructional television was also the centerpiece of a major education reform in El Salvador during the sixties and seventies. (Unless otherwise specified, information in this section is drawn from Mayo et al., 1976.) El Salvador embarked upon a reform of instruction for grades 7-9 in order to widen access to secondary education. Television was used to provide instruction in mathematics, English, Spanish, social sciences, and natural sciences. The use of television was embedded in a larger curriculum reform which included retraining of teachers, revision of instructional materials, and the building of new facilities.

The reform was very successful in widening the path to secondary school. In 1968, there were 19,104 students enrolled in grades 7-9; this increased to 65,390 in 1973. The government placed hopes on increasing the number of persons who would leave school with a ninth grade education to take training for middle level technical jobs.

The costs of instructional television were considerably lower in El Salvador than in American Samoa. The per student cost, based upon enrollments of 48,000 students and assuming 170 hours of programs, were calculated to be $24.35 per year in 1972. Carnoy (1976) estimated costs to be about $26 per student. He points out that this would come to about $780 per classroom of 30 students. This was almost 60% of the annual salary of a junior high school teacher in 1970 ($1,400).

The results obtained in El Salvador were mixed. Mayo et al. compared the performance of three cohorts of students (those who started seventh grade in 1969, 1970, and 1971). In the final two years, comparisons were made between students receiving instructional television and those not receiving instructional television but benefiting from other aspects of the educational reform. The ITV students fared better than non-ITV students in the seventh grade. In eighth and ninth grades, Mayo et al. conclude that the "advantages of ITV were not apparent."

The ITV students outperformed their non-television counterparts on tests of general ability. On achievement tests, between seventh and ninth grades, ITV students showed better gains in mathematics; gains in reading were about equal; results in social sciences were mixed; and in science, non-ITV students showed better gains than students learning science through television.

It was discovered that boys gained more than girls, and in general, television did not reduce the effects of student background variables (father's education, family wealth, and urbanization) on achievement. Over 85% of students were found to be continuing their education after the ninth grade, but half of them were enrolled in courses leading to university studies and not to preparation for middle-level technical jobs, as had been hoped for by government planners. University enrollments were not widened. Mayo et al. concluded at the time that students' "high educational aspirations are not realistic in terms of the tangible opportunities available to them in the near future."

By the end of 1972, some disenchantment with television was growing on the part of teachers. Mayo et al. note that the majority still believed that educational television could be an important teaching tool. But in later years, opposition to television grew, and the cost of television became an issue when teachers went on strike for higher wages.

Ivory Coast

During the seventies, the Ivory Coast also undertook an ambitious reform of primary education with television playing a leading role. (Unless otherwise indicated, information from this section is drawn from Kaye, 1976.) The strategy in the Ivory

Coast was to make use of television to increase the quality of instruction, which would allow for introduction of a policy of automatic promotion and great reductions in dropouts. Thus, even with the add-on costs of television and improved teacher training, cycle costs per graduate would be reduced.

The project began in 1971 with 21,000 first graders. The plan called for adding one grade per year. Over a fifteen year period, enrollments in primary schools were to be tripled, and by 1986, the entire 6-12 year age group would be enrolled in ITV schools. A thorough revision of the curriculum and upgrading of teacher qualifications was planned to accompany the use of television. There was also an ITV component for out-of-school adult groups.

By 1979-80, 15,635 classes were receiving instructional television, representing about 84% of all students (Hawkridge and Robinson, 1982) or in excess of a half million students. Lessons were broadcast covering French, reading, writing, mathematics, hygiene, moral education, civics, environmental studies, and physical education.

Carnoy (1976) estimates a cost of $13 per student per year for 1976, based upon enrollments of 336,000 students.

We did not find published data with respect to student achievement. Hawkridge and Robinson (1982, p.163-164) refer to a series of studies undertaken by a team of researchers from the University of Liege in Belgium and observe that:

> Interpretations of the results of testing the students differ. The Belgians found that many students did not master the first grade curriculum; this was true in television schools and those without television. It caused problems in second grade in television schools, where the curriculum was based on mastery having been achieved in the previous year. Students in television schools who repeated first grade did better the second time but only rarely did they achieve mastery. The team noted that students had difficulty in particular with graphical representations. On the other hand, it seems that television teaching was most effective in teaching spoken French, with the children of television schools improving their proficiency in the language markedly more than those in other schools. Less satisfactory progress was recorded in written French, and changes are to be made in the methods of teaching the written language. Similarly, changes have already been made in the content and pedagogy of the modern mathematics programmes, which were initially radically new to both teachers and students...

Hawkridge and Robinson also report that the information collected by the Belgian team shows that the use of television helped equalize educational opportunities in rural areas, that the "range of differences in standards between the best and poorest television schools is small when measured by student achievement on tests. Some of the rural schools are in fact among the best now." (p.164).

Kaye (1976) notes that the use of television in the Ivory Coast brought about a reduction in rates of repetition and drop-out, and unit costs per graduate were lower than under the traditional system. Unfortunately, according to Kaye, only a quarter of graduating students would find places in secondary schools.

Despite the comparatively modest annual per student costs, the Ivory Coast apparently found television too expensive and no longer uses it in schools.

Niger

Niger turned to television during the sixties as a means to help overcome an acute shortage of trained primary school teachers and to inject modern methods of thought, expression, and teaching into the school setting. (Unless otherwise indicated, information in this section is drawn from the Clearinghouse on Development Communication, 1982.)

Lessons were broadcast daily in French and arithmetic. Classroom monitors, who lacked the qualifications of trained teachers, were supported by short training courses and in-service education via radio. About 700 children were reached during a pilot phase; this rose to 9,000 in 1975.

The use of television appeared to have a strong impact on reducing school dropout rates. During the sixties, dropout rates in Niger approached 40%; 674 of the original 716 students who began Tele-Niger classes in 1966 completed the four-year cycle in 1970 (this represents a dropout rate of less than 6%). Attendance was also found to be considerably better than in traditional classes.

There seems to be little readily available information on student achievement. The Clearinghouse on Development Communication (p.64) notes:

> The problems identified in various studies relate to the use of French in the broadcasts and to the quality of education received by students in the televised classroom. In particular, TV students performed less well than students in the traditional classroom in standardized math and grammar tests. To help assuage this problem, a fifth year was added to the televised

curriculum in 1970.

We were unable to locate cost information relevant to years when coverage of Tele-Niger expanded beyond its experimental phase. Carnoy (1976) estimated costs for 1969 based upon 800 students taking part in the pilot phase. This came to $1156 per year. Needless to say, this is not a good estimate of what television would cost in later years when the system expanded.

From what we can tell, television is no longer being used for primary school education in Niger. Apparently, opposition to the use of television was encountered from teachers' unions and from within the ministry of education itself.

Colombia

In the sixties, Colombia put television to the task of improving primary school instruction and providing in-service education to teachers. (Unless indicated otherwise, information in this section is drawn from Schramm, 1967.) Television was used to provide instruction in five grades. Each grade received ninety minutes of instruction in different combinations of subjects, which included mathematics, social studies, language, natural science, and music.

In 1965, television reached about 250,000 pupils. This resulted in an annual per student cost of only $4 (Carnoy, 1976).

There were mixed results with respect to student achievement. At the end of the first year's use of television, groups of television and non-television students were tested, 5,000 in all. Eight comparisons were made. In three of them, the television students significantly outperformed non-television students (grade 2 language, grade 5 mathematics, and grade 4 natural science). In five comparisons, there were no significant differences.

We found no information about whether television continues to be used in Colombia. Lyle (1982, p.292) suggests that the use of television may have been curtailed.

> The massive Colombian project reported in the 1967 series was attempting to upgrade rural primary schools through direct television instruction. It relied heavily on the use of American Peace Corps Volunteers for utilization supervision. For this the project was fortunate to have been the focus of the largest single cadre of volunteers in the entire Peace Corps. But even at the time of the case study, the Peace Corps was winding down.
>
> To the extent that the project has redirected its focus from rural to urban schools, the move may well have

been a necessary and wise one, simply because of the inability to continue providing adequate utilization supervision in the rural areas.

India

India also has had experience with the use of television in primary education. This came as part of the Satellite Instructional TV Experiment (SITE) and is described in Shukla (1979). Television was used to bring a daily 22 minute program of general enrichment to rural schools in six states. Lessons were aimed at grades one to five. The children were from disadvantaged homes, often the first generation in the family to attend school. The objectives of the programs were to help the children learn community living skills, develop awareness of the modernization of society, instill habits of hygiene, promote aesthetic sensitivity, and improve basic concepts and skills in mathematics, language, and technology. There was also a series of science programs for 9-12 year old children.

An evaluation of SITE showed mixed results. There were no significant differences between SITE and non-SITE children with respect to achievement in school subjects or in school attendance. It appeared that centralized development and production of program material failed to come to grips with the cultural diversity of the audience. The amount of information and pacing of messages proved difficult for the children to understand, especially in science. There did appear to be evidence that the language development of some children was positively affected. Although it appeared that teachers were not generally unfavorable to the use of television, they were not persuaded that television instruction was superior to face-to-face instruction.

We found no information on the current status of SITE in primary education in India or on costs.

Nigeria

There was a six year attempt (1959-65) to use instructional television in Nigeria. Different regions made use of television at different educational levels. In Lagos and Kaduna, television was tried at the primary level. According to Schramm (1967), Nigeria experienced almost every difficulty imaginable: jurisdictional conflicts between the Ministries of Education and Information, difficulties in transmission and reception, power failures, uncertainties about broadcast schedules, opposition from teachers, and lack of trained personnel of all kinds. Perhaps the most telling point was a discovery that three-fourths of the television sets found in schools were inoperative.

Estimated annual costs (for Lagos) were $6 per student for about 26 hours of instruction, based upon 17,200 students (Carnoy, 1976). We found no information about the educational

effectiveness of the television lessons.

Conclusions

Taken together, the diverse experience of these seven countries with the use of instructional television for primary education has been disappointing. The overall impression is that the use of television can be expensive and that it contributes little (in some cases, nothing) to student achievement. Television often arouses strong opposition on the part of teachers and sometimes resistance on the part of students. There is a striking lack of success in upgrading television use from an experimental phase to a permanent feature of national education.

However, care must be taken when trying to draw conclusions about using television as a medium to deliver primary school education in developing countries. It may well be the case, bearing in mind the earlier discussion of the medium versus method issue, that unlike radio, a satisfactory model for instructional television programs for the primary school classroom has not been found.

Television as a Policy Option. Educational policy makers in developing countries who may wish to use television to deliver primary education should ask the same questions asked for radio and some other questions as well. These would include the following:

- Has consideration of the possibilities offered by television followed an adequate consideration of the possibilities offered by radio?
- Given the generally disappointing results with instructional television in other developing countries, what suggests that things could be different in the present context?
- Would time and resources be sufficient to allow an experimental phase of activities to develop and test a model of television programming that "works" in the primary school classroom in a developing country?
- Could the chances of success in using television be improved by strategies (and possibly a combined use of related technology such as videocassette recorders) that would allow greater flexibility and teacher involvement in using television in the classroom?

3. **Computers**

People must be properly prepared to live in a society where most will encounter computers at workplaces, in private life, and in any other activity; we draw the attention of decision makers to their responsibilities in meeting effectively the new challenges to equity at national and international levels.

> In recent years, more and more countries have been making decisions on a national level to ensure the introduction of computers in education on a large scale, and more decisions are in preparation in many other countries, both developing and industrialized. Educational authorities all over the world should take into account existing scientific evidence and apply scientific monitoring and objective evaluation to a rapidly changing domain... (Stanford Symposium Statement, Stanford/UNESCO Symposium On Computers and Education: Which Role for International Research, 10-14 March 1986)

Discussion about the application of instructional technology in developing countries is increasingly becoming discussion about computers. Most often the interest in introducing computers in education, as the Stanford Symposium Statement suggests, stems from perceived social and economic imperatives rather than from a desire to use technology to improve or extend education. Although the generally declining costs of microcomputers in the 1980s have made introduction of computers a possibility for more and more countries, the question of affordability still looms large. Carnoy et al. (1986) point out that per student costs per contact hour for direct computer access are higher than costs many developing countries now incur for education per student per week. Nevertheless, many developing countries are now considering ways to begin introducing computers into their educational systems.

The literature on the use of computers in education in developing countries is scant and largely addresses problems developing countries are likely to face based on the experience of the industrialized countries. Our discussion of the possible use of computers at the primary school level is especially anticipatory.

The evidence now available suggests that the introduction of computers in education in both developed and developing countries has taken place mostly at post-primary levels. At the primary level, UNESCO (1986) reports "general measures" for introduction of computers in nine countries: Australia, Canada, France, Hungary, Korea, Mexico, Spain, the United Kingdom, and the United States. "Experimental measures" are reported for Argentina,

Belgium, Brazil, China, Colombia, Japan, Kenya, the Netherlands, New Zealand, and Senegal. However, UNESCO admits that the pace of change taking place in most countries makes it difficult to keep an up-to-date inventory. Assessing the extensiveness of computer use in developing countries is also complicated by the difficulty of obtaining information at a subnational level--where individual or groups of schools may be introducing computers without government assistance. These efforts often go undocumented.

Educational Uses

The possible educational uses of computers in developing countries can be anticipated by taking the experience of industrialized countries as a starting point. These uses, which in concept or practice are not always distinct, include the following:

Computer Literacy. There are numerous definitions of computer literacy. The most common element is, perhaps, the goal of preparing people to live in the "information society" or to "demystify" the computer. India and Mexico are two developing countries now embarking on national programs of computer literacy (Carnoy and Loop, 1986).

The applicability of the notion of computer literacy for developing countries is considered in Papagiannis et al. (1987). They contend that the idea of computer literacy must be broadened and that its educational agenda must be linked to the wider context of national development. They suggest three main dimensions of computer literacy:

(a) computer literacy as employment preparation--The authors see some value for employment-oriented technical training in computer-related skills but urge that these programs be kept small in size and confined to the upper secondary school level;

(b) computer literacy as informatics--The authors contend that an understanding of the social, economic, political, and cultural dimensions of information technology will be important for national development and should aim at closing the gap between the rich and the poor. They recommend programs of adult education that address the issues of information technology and its role in development and recommend providing opportunities for greater access to microcomputers and other information technology. The issues of information technology for national development might also be addressed in social studies courses in schools--even those where computers have not been introduced;

(c) computer literacy as productivity enhancement--The authors point out that "computer literacy as productivity

> enhancement relates to learning to use computers to improve non-computer related activities," (p.78). They suggest that the use of productivity software will and should follow a less "personal" course than it has in industrialized countries. They urge that computer literacy as productivity enhancement should be oriented toward the goal of national development and might take place within demonstration projects in health, nutrition, and community development. The aim would be to promote greater local control and self-reliance in the development process.

Direct Instruction. Computers have been used as a means to provide direct instruction in school subjects like mathematics, language, and science. Distinctions--often value laden--are made between instructional strategies used in computer instruction: drill and practice, tutorials, games, simulations, and problem-solving. Friend (1985) argues that these categories are not always distinct. She notes that the common distinction between tutorial programs and drill and practice is not always clear, since tutorial programs often contain practice components and that well-designed drill and practice programs allow students to abstract to general principles from the exercises given.

In 1985, about 77 percent of the time spent in computer use in elementary schools (below grade 4) in the United States was for drill and practice in reading, language arts, and arithmetic (Becker, 1987b).

Programming. Computers have also been used in schools for the purpose of teaching programming. This is especially true at the secondary level. In the United States, for example, about 42% of the computer time in high schools is devoted to instruction in programming (Becker, 1987b). The intention here is often two-fold. Advocates of teaching programming argue that this will (a) lead to a better or more rapid development of higher order cognitive skills, or (b) that programming skills will be useful in finding employment. At the primary level, there is sometimes an effort to teach what Friend (1985) refers to as the "beginner's programming language." These include languages such as BASIC, LOGO, and Small Talk.

Lockheed and Mandinach (1986) tie a declining interest in post-secondary computer-related careers now being witnessed in the United States to poorly taught pre-college instruction in programming. With respect to the external efficiency of recent efforts to teach programming, they cite a study by Linn (1985, p.22) that points to the conclusion that:

> Programming instruction at the pre-college level was inadequate in scope, depth, and choice of language. In most cases, students enrolled in college courses had to unlearn misconceptions and poor techniques before they

could profit from college instruction.

Computers as Tools. There appears to be an emerging consensus on the value of teaching students to use computers as productivity tools either within existing school subjects or in special courses. This involves instruction in the use of spreadsheets, word processors, outliners, and database managers.

Compared to computer-assisted direct instruction and programming, using computers as tools appears to be gaining rapidly in relative importance in schools (Hunter, 1987). The merits of the "tools" approach are considered in Lockheed and Mandinach (1986). They cite the enormous difficulties in integrating computers into the curriculum. They suggest an "applications-based computer course" as an alternative to full curriculum integration and programming courses. Such a course would emphasize generalizable skills through instruction in use of the various applications packages mentioned above and would be linked to the regular school curriculum through collaborative teaching.

Papagiannis et al. (1987, p.61) believe that using computers as a tool may be a fruitful approach for developing countries. They contend:

> ...that the link between these (enduring) goals (of education) and what can be practiced using the various data-base management programs, word and concept-processing (outlining) programs, spreadsheeting, quantitative and qualitative data-management programs, within the various subject-area specialties, are precisely the skills we urge our teachers to prepare students in. In other words, our traditional educational aims of improving problem-solving, problem-posing and critical understanding through the use of productivity tools and creative programs in the subject-areas could become a reality in practice...

Besides the above categories of classroom use, computers may also be used in education for various diagnostic, monitoring, and testing purposes (computer-managed instruction) as well as for school administration tasks.

Hardware Configurations and Access

There are essentially two options that developing countries might follow with regard to selection of computer hardware for education. One uses a minicomputer to route instruction to individual student terminals. These systems tend to use complete curriculum packages and offer features for diagnosis, evaluation, and monitoring of student progress. Such a system has made it possible to run more powerful software and offers the potential

advantage of greater ease in classroom management. With a minicomputer system, software does not need to be passed around and generally only a single system manager, rather than a host of teachers, must be trained. (AID's Learning Technologies Project is currently evaluating the Control Data Corporation/WICAT minicomputer application in a primary school in Grenada.)

More common, however, will be a configuration using microcomputers. These may be installed in different classrooms throughout the school or placed together (and sometimes linked together) in a single room. UNESCO's (1986) survey of 43 countries found the trend to be toward the one-room "computer laboratory."

Schools may begin acquiring microcomputers without making as large an initial investment as with a minicomputer system. Microcomputers offer more flexibility with regard to how they might be used in classroom activities and in software selection.

Access and Equity

Both the availability of hardware in relation to the number of students in a school and a school's curriculum decisions affect the amount of access a student has to the computer. Even in the industrialized countries, there is a great deal of variation to be found with respect to access. In the United States, by spring 1985, five out of six primary schools had acquired computers for instruction; at the secondary level, the majority of U.S. high schools had fifteen or more computers for instruction (Becker, 1987b). In the space of two years (1985-87), the computer to student ratio in elementary schools is estimated to have gone from about 60 to 1 to about 40 to 1 (Becker, 1987b).

Other industrialized nations have considerably fewer computers available in schools. UNESCO's (1986) survey found that for 30 countries having a national policy for the use of computers in education, the average number of computers per school was five.

In developing countries, it is very likely that schools interested in introducing computers will attempt to get along with even fewer machines, perhaps one per school. It is difficult to predict the possible effects or even how one might organize instruction in such a "lone or sparse micro" scenario.

The use of computers in education raises questions that access to computers may be affected by race, ethnicity, gender, and social class (see Carnoy et al., 1986; Lockheed and Mandinach, 1986; and Papagiannis et al., 1987, for a discussion of these issues).

With respect to possible gender bias in access to computers in education, Papagiannis et al. (1987, p.50) put the issue as follows:

> While access to computers at the primary level showed little or no gender bias, at the secondary level, access and use by male students was much higher than for females. This parallels the predominant use of microcomputers in math and science, where gender bias has long been entrenched.

The effects of gender on computer access may disappear when contextual variables are taken into consideration. Becker (1987a, p.14) notes the following:

> Boys and higher-ability students also use school computers disproportionately, although not in all respects. The sex discrepancy is greatest where computers are <u>least</u> connected to school curricula--in before- and after-school activities, in game playing in secondary schools, and in elective programming activities in elementary school. Parity between boys and girls is most often found in computer-assisted instruction activities, in writing and word processing, in elementary-level learning games, and in programming activities in secondary school. Although people usually perceive girls as being underrepresented in programming activities, on a national basis the differences are small in high schools, especially where curricular activities exist for entry into programming classes...

Williams' (1987) study of computer access and student attitudes in Trinidad and Tobago confirms the importance of the connection to the school curriculum when looking at the question of gender and access to computers. She found that within schools where computers are being used in instruction, females had greater access than males, but that outside of school, the reverse was true.

A second access/equity issue has to do with how computer use within classrooms is affected by characteristics of students such as race and social class. It is often pointed out that students from more well-to-do families are more likely to receive exposure to more "cognitively exciting" software like LOGO and that less well-to-do students are likely to be exposed to the "drudgery" of drill and practice software. But the charges of inequity in this comparison are not clear-cut since the benefits of computer-assisted instruction for remediation in basic skills have been demonstrated and the benefits of LOGO for the development of thinking skills have not.

How these issues of access/equity suggested by the experience of industrialized nations play out in the context of developing countries cannot be predicted. The access/equity questions within and between computer-using classrooms are certainly likely to be of less concern to policy makers than the questions of disparities between the "have's and have not's," that is, between public and private schools, between urban and rural schools, and with respect to a choice between wider access to computer literacy at lower grade levels and a more focused employment-oriented concentration at higher levels.

Likely Effectiveness

There have been numerous summaries and interpretations of the literature on the effectiveness of computer-assisted instruction (Carnoy et al., 1986; Papagiannis et al., 1987; Burns and Bozeman, 1981; Vinsonhaler and Bass, 1972; Forman, 1982; Rogosta, Holland, and Jamison, 1982; Hartley, 1978).

For our purposes, a useful benchmark was established by Kulik, Kulik, and Bangert-Drowns' (1985) meta-analysis of 32 research studies on the effects of computer-assisted instruction on the achievement of elementary school pupils in various school subjects. They report an average effect size of .47 (considered to be high) for the use of computer-assisted instruction. Other meta-analyses have shown effect sizes of similar magnitude (Niemiec and Walberg, 1985).

One problem with the meta-analyses is that the studies upon which they are based are becoming dated. Becker (1987a, p.5-6) observes that 99% of the studies drawn upon in the meta-analyses use "computer systems, software, and social organization of implementations that characterize, at most, one or two percent of all the instruction in traditional academic subject matter using school computers today." Only a few of the studies in the meta-analyses reflect the use of microcomputers. However, a review of research on computer effectiveness in instruction (Roblyer, Castine, and King, forthcoming) that takes into account more recent studies found an average effect size of .53 from studies on the use of computers at the elementary school level.

The syntheses of studies on the effectiveness of computers in education are of limited value to educational policy makers in developing countries, where the educational circumstances are far different from those in more developed countries and where empirical investigation into the effectiveness of computers in education is only beginning. Nevertheless, the evidence now available does provide justification for the expectation that instruction delivered by computers will positively affect student achievement. This is a useful starting and reference point for the more situation-specific investigation that must take place in developing countries.

Again it must be stressed that achievement in traditional academic subjects is only one of many possible outcomes of interest to educators in developing countries. Attention must be given to assessing the effects of computer use on motivational and other attitudinal changes toward self, school, science, and technology. Similarly, the acquisition of even basic level employment-oriented computer skills is likely to be seen as more useful in developing countries than in industrialized countries. Especially in situations where computer literacy is the goal, it will be important and by no means easy to find appropriate ways to evaluate the effectiveness of these interventions.

Constraints

We find in the literature mention of four major constraints to the widespread use of computers in education in developing countries. These are costs, software suitability, operating requirements, and teacher training.

Costs. Friend (1985b) maintains that the cost of purchasing and operating computers is the main reason why computers have not been more widely used in developing countries. Carnoy and Loop (1986, p.9) note the paucity of studies of costs, cost-benefit, and cost-effectiveness. They suggest that it is difficult to assess the cost for using computers in developing countries because:

> At present, most computers are used in environments where maintenance and use infrastructures are well-developed and there is a market for such services (hence they can be priced). In many developing countries this is certainly not the case (p. 9).

Carnoy and Loop also mention that no cost-benefit studies on the use of computer-assisted instruction have been undertaken. Cost effectiveness studies that have been undertaken suggest that while it appears that computer-assisted instruction can be compared to other technologies, the results so far are too sparse to draw conclusions about the cost-effectiveness of computers compared with other technologies.

Levin, Glass, and Meister (1984) estimate the costs of providing computer-assisted instruction through a fully-equipped computer laboratory in the United States. The costs to a school with 736 students providing 23 sessions (10 minutes) per day on 32 terminals would be about $119 per student per year at 1980 prices. The authors point out that even with falling prices for computer equipment, the per student costs of computer-assisted instruction in a fully-equipped computer laboratory are not likely to be reduced, since the biggest component of these costs is for salaries of persons running the laboratory.

Such a relationship is likely to be different in developing countries where costs of hardware are likely to be larger in relation to salaries. In general, however, without knowing what a country hopes to accomplish with computers in the classroom, the hardware, software, and personnel available within schools, the number of students who can be served by the computers, the specific conditions under which students will work with computers, and the effects of possible cost reductions through using computers after school hours for other purposes, it is impossible at this time to speak with assurance about the likely educational costs of computers in developing countries.

Software Suitability. Concerns about the transfer of software to developing countries are widespread in the literature. UNESCO (1986) reports that the problem consists of the suitability of imported software for the curriculum, the suitability of software in various linguistic/cultural settings, and the portability of software across the hardware and operating systems used in different countries.

UNESCO maintains that governments pay insufficient attention to the question of software in their plans. While many countries appear to be producing software of their own, UNESCO notes that even a software exporting country like Australia depends for the most part on imported software because domestic production is insufficient. Of equal concern, available software is often not adequately evaluated and validated. UNESCO (1986, p.16) notes that in the United States, there are 20,000 educational programs on the market, and it is estimated that only about 10% of these have been assessed.

Hebenstreit (1986) cites the problem posed by copyright arrangements for software. If developing countries are not able to make legal copies of software packages and must purchase as many copies as there are computers, the possibilities for using computers in the classroom will be severely constrained.

In educational policy discussions that will take place in developing countries during the coming years, the issue of software suitability could raise the question of educational relevance more forcefully than anything experienced since Third World countries began refashioning curricula and curriculum materials following independence. In most instances, developing countries intending to use computers in education will be forced to rely on imported software. Policy makers considering the insertion of imported software into an existing curriculum must ask:

- Where in the curriculum is this appropriate?
- How much of an existing curriculum might be

replaced or supplemented by imported software?

- Do cultural or linguistic mismatches between imported software and local circumstances offend national or regional pride? Do they also affect learning?

Freeman's (1987) study of a computer classroom in Grenada is an early attempt to explore some of the problems Third World children encounter while working with imported educational software.

Operating Requirements. The problems posed by heat, humidity, dust, access to necessary sources for maintenance and repair, and access to satisfactory electrical current in developing countries are obvious to most people and need not be elaborated on here. Phillips (1987) and Freeman (1987) describe how computer-assisted instruction in Grenada is affected by system reliability and poor electrical supply.

Teacher Training. There is wide consensus that teachers are usually not adequately prepared to operate effectively with computers in instruction (Hebenstreit, 1986; Carnoy et al., 1986; UNESCO, 1986; Lockheed and Mandinach, 1986). Carnoy and Loop (1986, p.6) describe the situation as follows:

> Few countries seem to have taken the necessary steps to prepare teachers to use computers, even when hardware is installed in schools. There is also little agreement on how to prepare teachers beyond short term courses (6-15 days) that merely help understand how to use computers in the classroom. The problems of implementing even this type of training are apparently great. Those countries most committed to computer training for teachers (Sweden, UK, France, Australia, and Canada) have reached only 25% of their teaching force. In most other countries, less than 5 percent of teachers have taken such courses (2 percent in Latin America). Even though some countries have recently launched national teacher training programmes (India, Chile, Korea, Cuba and Mexico), most are not devoting the necessary resources to training, but rather to purchasing hardware...

Likely Future Directions

The widespread introduction of microcomputers into schools in the United States began prior to a clear demonstration of their effectiveness as educational tools, and, in many cases, in the absence of systematic planning on how they would be used. We see a similar pattern emerging in developing countries.

Developing countries, especially in Latin America and the Caribbean, are becoming increasingly interested in the use of computers in education. This trend cannot yet be fully documented from the literature, and until we are able to do so, we offer it (we hope) as "reliable hearsay" derived from numerous conversations with educators, government officials, researchers, computer specialists, and manufacturers.

We believe that computers are an object and instrument of instruction unlike other instructional hardware. That is to say, few countries find it important to offer education about television and radio. The importance of learning about computers may start a trend in which students will increasingly learn through computers.

The importance of learning about or through computers is largely a concern for relevance: education must be relevant to an emerging world economy where computers will play an important role--an economy in which few countries wish to fall further behind. A concern for keeping up in the world economy, described by some as the pursuit of equity at the international level, is likely to force acceptance of inequities at the national level. Developing countries may judge that it is necessary to give some children experience with computers, even in the face of great uncertainties that this experience can be easily generalized throughout the entire national educational system. Although this consideration makes it more likely that the use of computers will be concentrated at post-primary levels, applications at the primary level can also be expected to increase. This will be pushed in part by government authorities' intentions to keep up with private schools.

Primary school children in developing countries will have differential access to computers based upon the financial means of their countries and families. Some children will have more favorable opportunities because they attend private schools or because they have a computer at home. Others are likely to have more limited access to whatever machines are available in the schools they attend. Perhaps this might be only one machine per school, where a microcomputer serves a multipurpose function for school administration, computer literacy, direct instruction (possibly concentrating on either remedial work or acceleration), and service as part of a school "library." How effectively one microcomputer, or at best a very few, might contribute to primary education in such a "lone or sparse micro" situation remains to be studied.

Finally, we see that children in developing countries are likely to encounter possibilities for computer-assisted education through private learning centers. As costs of hardware and software continue to fall, we expect to see a proliferation of

private learning centers offering a variety of services to the public: computer sales and service, management consulting, data analysis, training in the use of computers, and computer-assisted instruction in subjects taught in schools. These may be well capitalized ventures possibly supported through franchises with manufacturers of computers from abroad or less capitalized local cottage industries.

Private learning centers will compete for private funds parents now spend on outside tutoring for their children. Such tutoring is often conducted prior to a student's sitting for examinations required to enter or graduate from secondary school. It will be interesting to see how effectively private learning centers are able to use an imported and possibly eclectic curriculum of off-the-shelf software in subjects like language, mathematics, and science to improve student performance on national examinations in these subjects.

Conclusions

Computers have become, as many suggest, a "cultural phenomenon." Apart from the obvious functions they perform in the workplace, the phenomenon of computers is generating new vocabulary, symbols, images, and metaphors that are rapidly becoming part of both everyday culture and educated discourse throughout the world. The computer phenomenon is increasingly making itself felt in developing countries.

It is too early to draw any conclusions about how computers will contribute to the production of learning in schools in developing countries. It is obvious, however, that it is now too late for discussions about whether the use of computers for education in developing countries is a good idea or not. Many countries have already decided to have a look for themselves; others are soon to follow. It is important that we learn what they learn.

Computers as a Policy Option. Educational policy makers in developing countries who may be considering the introduction of computers into education should ask the following questions:

- What can computers do for instruction that conventional formats can't do?
- What specific educational uses of the computer are to be attempted: direct instruction, computer literacy, programming, or learning to use computers as tools?
- Are one or more of these uses feasible and affordable at the primary school level or should they be postponed to post-primary school education?

- What software will adequately deliver the intended instruction?
- What hardware can be obtained and serviced locally to run the software selected?
- Will technical and financial resources be sufficient for training teachers to work with computers?

4. Videodiscs

Videodisc technology has been heralded as one of the richest possibilities for the delivery of instruction. It weds television's capacity to provide audio and visual material (including still photographs, motion, graphics, and text) to the computer's capacity for interactivity. It provides unmatched possibilities for the simulation of reality within a controlled instructional setting. The relatively high costs of this technology have so far precluded wide application in schools, even in affluent societies. Continuing technological developments seem likely to cause this to change. Although the most immediate applications in developing countries are likely to be in the area of higher education and technical training for specialized personnel, it is not inconceivable that, as with computers, primary school students in some places will encounter videodisc technology as part of libraries of the future, in private or public learning centers, in well-equipped schools, or at home.

Optical laser discs currently being used can hold over 100,000 still frames of visual material (or about 25-30 minutes of motion). An audio track of less than one hour would accompany 100,000 frames. The information stored on discs is read by a videodisc player and presented on a television monitor. Donahue and Donahue (1983) describe four levels of videodisc instructional hardware:

- Level 1: The videodisc system consists of a videodisc player and a television monitor and possibly a remote control device. It functions in a fixed sequence "slide show" mode. The user controls point of entry. Instruction is described as linear;
- Level 2: The videodisc player has a computer component which allows some branching, greater speed, and more user control;
- Level 3: The videodisc player is coupled to a microcomputer, which allows for more

complex programming and interactivity;

- Level 4: The system consists of two videodisc players, permitting more complex branching and almost instantaneous feedback. Such systems are used for simulated instruction such as pilot training.

The cost of an interactive "level 3" system is likely to run between $2500 - $3000. Estimates of costs for producing videodiscs vary. Donahue and Donahue (1983) estimate that a first copy of a "professionally produced one-hour instructional disc" is likely to cost more than $100,000. Costs of additional copies of the disc are around $20.

Interest in the use of videodiscs has heightened with the emergence of what is referred to as CD-ROM (compact disc-read only memory), CD-I (compact disc-interactive), and CD-V (compact discvideo). Information on these 5 1/4" discs is stored in digital form and in great volume (perhaps around 550 megabytes and going higher). The CD-ROM standard is being applied to storing and retrieving large databases and library materials. Many people expect that the development of a multi-purpose compact disc player will make it possible to read all kinds of information, from computer data to film and music, with one device.

The interactive CD-I technology is likely to become of considerable interest to educators. The 5 1/4" CD-I discs will hold about 650 megabytes of information (storage of up to 1.3 gigabytes is foreseen for the future). Current capabilities make it possible to provide a 2-hour sequence of interactive instruction with high fidelity audio. The high resolution video will rely on still pictures, text, and graphics. A CD-I disc will be "mastered" for about $5000, and copies will cost about $30.

What makes CD-I technology so interesting is the fact that it will bring down dramatically the costs of an interactive videodisc system. The Sony and Philips Corporations expect to have an inexpensive CD-I player on the market by the end of 1987 that will make interactive videodisc technology a possibility for homes and schools. The CD-I player will connect to a television set and interactivity will be achieved through a remote sensing device (or other peripherals). The built-in computer will not only drive the system but offer some computing capability as well. The player is expected to sell for about $500.

One of the current limitations of CD-I is that it does not easily accommodate digitized full-motion video. This will become a possibility soon, however. Recently, General Electric/RCA announced a prototype machine called DVI (digital video

interactive) that does permit the use of moving video in interactive instruction (Ofiesh, 1987).

Much of the attention given to videodiscs so far has concentrated on the hardware. Halloway (1982, p.133) warns that "less is known about teaching and learning using the videodisc than is known about the engineering of the technology." Hanafin (1985, p.236) remarks that "little empirical research of any type has been published to support the differential effectiveness, the effects on learning, or the validation of the basic assumptions of interactive video."

A considerable amount of research needs to be done on how best to use the various capabilities of interactive video for designing effective instruction. Halloway (1982, p.135) argues:

> The multimedia aspect is more than having everything (motion, sound, graphics) available at once, though that is convenient. The advantage for instructional design is having the choice, in being able to pick the best mode for the learning goals. Research is some help in this selection. For instance, adding sound to pictures is not necessarily an improvement and may even detract from learning. 'Real' pictures rarely increase learning; research suggests line drawings often work better. In these and other 'areas the computer alone may be quite sufficient to assure a very high degree of learning without the videodisc' (Bork, 1980). The broad selection of media in combination can provide the best fit between learner and lesson.

For developing countries, the instructional design issues are not likely to be of great interest in the immediate future. Few are in a position to marshall the financial or human resources to engage in professional instructional design of videodisc instruction. What will be of interest is the development of effective software to run on the low cost interactive systems. Such software could be affordable if it is "generic" enough to be useful in several countries, thereby reducing costs. Instruction in mathematics is something that might lend itself to this kind of treatment.

Hanafin (1985) believes that interactive video does not differ greatly from "allied technology" such as computers from either learning or cognitive perspectives. In a parallel sense, we anticipate that the application of videodisc technology in education in developing countries will not differ significantly from the application of computer technology where a high premium is assigned to using computers for direct instruction. Low cost interactive video systems are likely to find use in homes (possibly replacing the videocassette recorder), especially as motion pictures and recorded music become available on compact

discs and systems come to serve both educational and entertainment functions. Interactive video is also likely to find instructional use alongside microcomputers in private learning centers.

Videodiscs as a Policy Option. At the moment, educational policy makers in developing countries are not pressed to come to terms with the possibilities offered by videodisc technology. They may wait until low cost videodisc players have proved themselves, software becomes widely available, and experimental work has been conducted that demonstrates where and how the use of videodiscs could be cost effective.

Given the high fixed capital costs associated with producing high quality instruction on videodiscs, the use of videodiscs in education in developing countries is likely to occur through reliance on imported software. The quality and relevance of this software will be an issue. Ways must be found to help educators in developing countries be intelligent consumers of videodisc software (and computer software as well) prior to the day they are able to produce their own.

5. Hand-held Electronic Devices

We consider two varieties of hand-held electronic devices: microprocessor-driven learning aids and calculators. It appears that neither is widely used in instruction in developing countries at this time. However, the instructional possibilities they offer and their low cost, ease of use, and ability to run on batteries (sometimes solar cells) recommend them for consideration as appropriate tools for supporting primary school instruction.

Electronic Learning Aids

One can currently buy numerous electronic games that offer educational content. Some of these operate with microprocessors similar to ones used in computers. These devices differ from computers in that they are much simpler to use, are less expensive, are not usually programmable, and deliver only instructional routines resident in the device or that might be added with insertable modules.

The most well-known of the electronic learning aids is the series produced by Texas Instruments, Inc.: the Speak & Spell, Speak & Read, and Speak & Math. These "talking" devices utilize a keyboard, synthetic speech, and an eight-character alphanumeric display to offer interactive drill and practice in language and arithmetic skills. The aids weigh just over one pound and sell for about $40 in retail stores in the United States. Other electronic aids to appear recently include Coleco's "Talking Teacher" and Video Technology's "Electronic Lesson One."

The first known effort to examine the use of electronic learning aids in classrooms in a developing country is described in Anzalone and McLaughlin (1984). This was a pilot study that involved the use of the Speak & Read and Speak & Math in primary schools in the Kingdom of Lesotho.

The purpose of the study was to determine whether the use of existing models of the Speak & Read and Speak & Math was feasible in a developing country like Lesotho, how the aids fit into the structure and processes of the classroom, and whether pupils' mastery of English and arithmetic was strengthened by use of the aids. The study ran for twelve weeks in five primary schools. The language aids were used in standards 3 and 4, and the math aids were used in standard 6. Pupils worked with the aids in groups of four for about one hour per day, two to five times per week, during the usual classroom time for English or arithmetic.

The study reported the following results:

Technical Feasibility. The aids were introduced into primary schools without great cost and preparation. The aids stood up well physically. Only 3 of 62 aids used required replacement, and none were lost because of poor housekeeping on the part of teachers. Pupils adapted easily to the synthetic speech contained in the aids.

Human Use Effects. Interviews conducted with teachers, administrators, and pupils showed a widespread belief that the aids were useful. The result of pupil observation shows maintenance of a high degree of involvement during periods when the aids were used. Both the interviews and observation demonstrated that it was feasible to use the aids in groups of four.

Learning Effects. The results of weekly tests of pupils' English word recognition and arithmetic demonstrated positive learning effects associated with use of the aids. For both language and arithmetic, pupils using the aids made larger gains in achievement than those not using the aids. In the cases of the language aid, the difference was statistically significant at the .001 level. For the arithmetic aid, the difference on the final test was not statistically significant but was so (at the .05 level) on the test given the week before. The aids had a greater impact on learning among the less able pupils. No significant differences in achievement were discovered between boys and girls using the aids.

The study concluded that it is feasible to use electronic aids to supplement primary instruction in a developing country like Lesotho. The study outlines a scenario whereby aids would be rotated among grades and schools. Under these and other assumptions, the cost of a 60 hour supplement of electronic drill

and practice (excluding batteries) was estimated to cost $.94. Anzalone and McLaughlin also concluded that more information was needed on the use of the aids over longer periods of time, in other country settings, and on the range and magnitude of possible learning effects.

We have found no other attempts to look at the use of this technology within the context of a developing country. Although the learning aids such as those used in Lesotho continue to be sold and new ones have appeared, there appears to be little interest on the part of manufacturers to improve their capabilities. Similarly, unlike microcomputers, the prices of electronic learning aids have not fallen during the past few years.

Calculators

Hand-held calculators, now often solar powered and selling for $5 or less, are perhaps the most affordable educationally-related electronic product available today. They are to be found almost everywhere in the Third World. The one place that they are noticeably absent is the classroom. In educational systems with which we are familiar, parents and teachers tend to be opposed to the use of calculators because of the belief that using calculators is likely to lead to inadequate mastery of number facts and development of computational skill.

The hand-held calculator does not strictly fall under our definition of instructional hardware because of our insistence that the device must be capable of offering instruction that could serve as an alternative to a lesson usually provided by a teacher or a textbook. The instructional use of calculators in the classroom would almost certainly require direct instruction from the teacher or from exercises in worksheets or another form of printed text.

We were unable to find any published studies of the use of calculators in schools in developing countries. There have been many studies undertaken in North America and Europe. A review of the literature by Suydam (1983) looked at over 175 studies, of which at least 75 explored whether the use of calculators in the classroom would have a deleterious effect on achievement in mathematics. In all but a few instances, achievement test scores were as high or higher when calculators were used in instruction (but not on the test) than when they were not used. Suydam found evidence that the use of calculators can help students learn number facts and can help in expanding a student's repertoire of problem-solving strategies.

A review of thirteen students by Sigg (1982) concluded that calculators were not detrimental to the development of computational skills. Seven of the thirteen studies showed gains

in computational skills when calculators were used in instruction; three showed improvements in students' attitudes toward mathematics. Less able students appeared to gain more from using calculators in instruction. The evidence regarding improvements in problem-solving performance was inconclusive.

Etlinger (1974) sees two roles for the use of calculators in mathematics instruction; the functional and pedagogical. The functional role foresees calculators being used to perform all mental calculations in solving problems. The pedagogical role foresees calculators being used as a tool to facilitate learning. The first role is likely to be unacceptable in most developing countries, and the second one is likely to be suspect.

If we ignore the possibilities offered by hand-held calculators we may miss an opportunity to improve the external efficiency of education in those settings where the majority of children leave school during the first few grades. In these situations, number facts are often poorly acquired and computational skill is weak. Proficiency in the use of calculators would give those children who receive no further education a means to solve many of the arithmetic problems they will encounter on the job and in daily life. Although this would create a dependency on an external device, there is no social stigma associated with using calculators for purposes of daily computation. And just as those of us who wear eyeglasses find this dependency preferable to not seeing properly, it is likely that being able to solve problems by using an inexpensive electronic device is preferable to not being able to solve the problems at all.

Perhaps "calculator literacy" should be taught in addition to basic mathematics. The use of calculators might kindle interest in and facilitate learning of more sophisticated mathematics than is now generally achieved in most of the primary schools in developing countries.

Hand-held Electronic Devices as a Policy Option. Further experimental work with electronic learning aids in classrooms in developing countries is necessary before recommending to educational policy makers that they be used. There appears to be little interest in shaping this technology to make it a practical, affordable, and effective alternative within primary school instruction in developing countries.

Similarly, educational policy makers are likely to have a difficult time exploiting the educational potential of inexpensive calculators. It may be difficult or impossible to convince teachers and parents that learning to use calculators is not detrimental to the development of computational skill or to demonstrate the advantages of "calculator literacy." Moreover, the use of calculators would have to be contained in an

instructional program. The development costs and the costs and administrative burden for training teachers and producing and distributing the materials required for such a program are likely to detract from the attractiveness of using this technology for instructional purposes in the classroom.

VIII. CONCLUSIONS AND OBSERVATIONS

Our purpose in this review was to determine how and to what extent learning technology in the form of instructional hardware is or might be significantly involved in the production of learning in primary school classrooms in developing countries. We have looked in some detail at the past experience of several countries and have tried to look ahead at the likely directions and possible consequences of the introduction of the devices of the "second electronic revolution." We reached numerous conclusions throughout the review about how the use of instructional hardware relates or might relate to the production of learning at various points in the process. We will close with some general conclusions and observations.

We defined instructional hardware as electronic presenters of instructional sequences that are significant enough in scope and curricular content to constitute an alternative to lessons usually provided by teachers or textbooks and similar printed materials. We find that the experience just reviewed points to the importance of the word alternative.

We found that instructional hardware has not been used in a way that would constitute a complete alternative to formal school instruction delivered by teachers. The one possible exception to this is RADECO, in the Dominican Republic, where learning by radio takes place in makeshift schools supervised by paraprofessionals. Even here, however, radio instruction is limited to one hour per day and is not meant to constitute a complete alternative to formal primary schools. The strategy for extending primary education by using instructional hardware as a less costly alternative to formal schools remains largely untried.

We did find that instructional hardware, especially television, has been used as a primary means of delivery in systems-wide attempts to upgrade the quality of primary school instruction. In several cases, this was in response to large shortages of trained teachers. Here, the use of instructional hardware was not intended to constitute an alternative to conventional instruction but as a component of a strategy that often included improvement of conventional instruction through such means as teacher training. It appears that as levels of teacher training rise or the numbers of certified teachers in the system grow, teachers resist (usually successfully) the use of television as a primary means of delivering school instruction. Few developing countries face the situation they did in the sixties where there were often massive shortages of trained teachers, low numbers of children enrolled in school, and very little perceived relevance or quality in the curriculum. The

conditions favorable for a strategy where instructional hardware is used as a catalyst in multi-faceted reform of all or part of an entire educational system have largely disappeared.

Instructional hardware appears to be most commonly used to deliver instruction that is not an alternative to, but rather an alternative within, regular school instruction. Within the context of regular school instruction, learning technology delivered through instructional hardware makes it possible to provide productive periods of instructional time superior to what routinely takes place in the usual primary school classroom in a developing country. These periods (where they have been delivered with instructional hardware) typically vary in duration from an hour per week to an hour per day. Often these periods have led to large gains in student achievement during the course of a school year. Our companion review, "Review on the Soft Technologies of Learning," suggests that these productive periods of instructional time result from application of methods and techniques emanating from our knowledge of the learning process. In the present review, we have found that these enriched segments of instruction can be delivered with varying degrees of efficiency with the use of instructional hardware.

The idea of productive periods of instructional time, delivered as an alternative within regular school instruction, is acknowledged in the BRIDGES model of learning production. The learning technology cluster of variables is conceived as being separate from (but related to) other "within school" variables. Learning technology should arguably be conceived as intrinsically involved in, and not separate from, such things as classroom management and instructional materials. The evidence, however, suggests the existence and potential effectiveness of a "within school" alternative provided by the application of learning technology during part of the school day.

In the future, whether learning technology delivered through instructional hardware will be used less for quality enhancement within the context of regular school instruction and more as an alternative to conventional instruction will probably depend on how well resources for education keep up with demographics. Up to now, using instructional hardware as an alternative to conventional school instruction has not been compelling for most developing countries. In the future, however, instruction delivered through instructional hardware may be an alternative to providing nothing, and the use of instructional hardware could well be not just compelling but inevitable.

IX. AGENDA FOR FUTURE RESEARCH AND IMPLEMENTATION

The preceding analysis, conclusions, and observations point to recommendations for an agenda for future research and implementation for using instructional hardware to improve and extend primary education in developing countries. It is a joint agenda for investigators and policy makers--a short list of what we believe to be the most promising avenues of activity.

We would first note that the use of instructional hardware is likely to be more attractive at post-primary levels. Interventions that rely on child/machine interaction are likely to be seen by many as incompatible with primary school's traditional mission of socialization of the child--no matter how effective the intervention proves to be. Nevertheless, in situations where there is acceptance that productive periods of instructional time mediated by the use of instructional hardware are either desirable, inevitable, or both, we contend the following.

Of the instructional hardware we reviewed, radio continues to offer the most promise of being an effective and affordable deliverer of instruction on a mass scale. The interactive radio model has set a standard against which the success of future applications may be judged. For the future, the priorities for research and implementation for the use of radio in primary education in developing countries are these four:

- More needs to be learned about the experience of all those countries reportedly using radio for primary school education but whose experience does not figure into the literature. How extensive is this experience? What are the successful models? Do they share common characteristics? What lessons can be drawn so as to allow greater generalization about the use of radio in primary school education in developing countries?

- We need to have a better understanding of the barriers to acceptance of the interactive radio model. At the moment, we can only speculate why more countries have not decided to adopt the model. In view of the investments already made and the results that

have been achieved, speculation is no substitute for empirical investigation.

- The RADECO model for extending primary education through radio seems especially promising and likely to be relevant for countries that come to experience difficulty in stretching resources to keep pace with population growth. Assistance should be provided to countries prepared to adopt or adapt the RADECO model and share this experience with the international community.

- It would be useful to investigate the introduction and implementation of the interactive model following a strategy that is less concerned with demonstrating radio's effectiveness (this has already been demonstrated) and more concerned with demonstrating the development of local expertise, commitment to quality, identification with the lessons produced, and sustainable institutional capacity for future implementation.

The other area on the joint agenda for research and implementation with respect to instructional hardware and primary education in developing countries has to do with future applications of computers and associated technologies. Although the industrialized nations are selling an increasingly large number of computers to developing countries, very little assistance is being provided to investigate how computers might be used most productively in classrooms. We recommend exploration in four areas:

- We must look for viable and affordable uses of the computer in situations where only one or a few microcomputers can be introduced. What difference does it make to have a computer present in the school? Can effective activities for individuals, groups, or the entire class be designed so as to revolve around the use of a single microcomputer?

- We need to discover the most effective approaches that integrate computer literacy and direct instruction in traditional school subjects.

- In countries where successful national or regional curriculum development activities

(such as in the Caribbean) have produced materials that are widely used, it would be useful to explore the development of related, high quality educational software. It would be unfortunate if decisions about the potential effectiveness of computers in education in developing countries are made entirely on the basis of software produced for markets in industrialized societies.

- Some attention should be given to the effects of using computers for primary education indirectly through teacher education. The use of computers, especially if linked to videodiscs, would be feasible, manageable, and affordable for many individual or groups of teachers' colleges. Such applications would allow the modeling of effective and ineffective teaching behaviors and a good means to teach methods for diagnosis of pupil difficulties in different subjects.

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